12/2450

INSTRUCTION MANUAL

model 171
PULSE GENERATOR

E-H RESEARCH LABORATORIES, INC.

12/2450

MODEL 171

PULSE GENERATOR

Serial No._____

E-H RESEARCH LABORATORIES, INC.
163 ADELINE STREET · OAKLAND, CALIFORNIA 94607 · (415) 834-3030 · TWX-910-366-7258
IN EUROPE: E-H Research Laboratories (Ned) N.V., P.O. Box 402, Eindhoven, The Netherlands

Units, abbreviations and prefixes of the International system of Units (SI) are used in this manual. Discrepancies may be noted between the terms used in the text and the instrument panel markings (e.g.; hertz, kilohertz, megahertz for cps, kilocycles, megacycles, etc.)

The National Bureau of Standards announced its approval of the SI in February 1964, and subsequently the document was adopted by congress as a national standard.

WARRANTY

E-H instruments are warranted to be free from defects in material and workmanship for one year. For in-warranty repair of this instrument, contact E-H Research Laboratories, Inc., Customer Service Department and provide:

a. Instrument model number and serial number.
b. Details concerning the nature of the malfunction.

Shipping instructions, or repair information and parts will be sent to you promptly.

TABLE OF CONTENTS

SECTION 1 SPECIFICATIONS.....1-1

SECTION 2 OPERATING INFORMATION.....2-1

SECTION 3 THEORY OF OPERATION.....3-1

SECTION 4 MAINTENANCE.....4-1

SECTION 5 PARTS LIST.....5-1

SECTION 6 DRAWINGS.....6-1

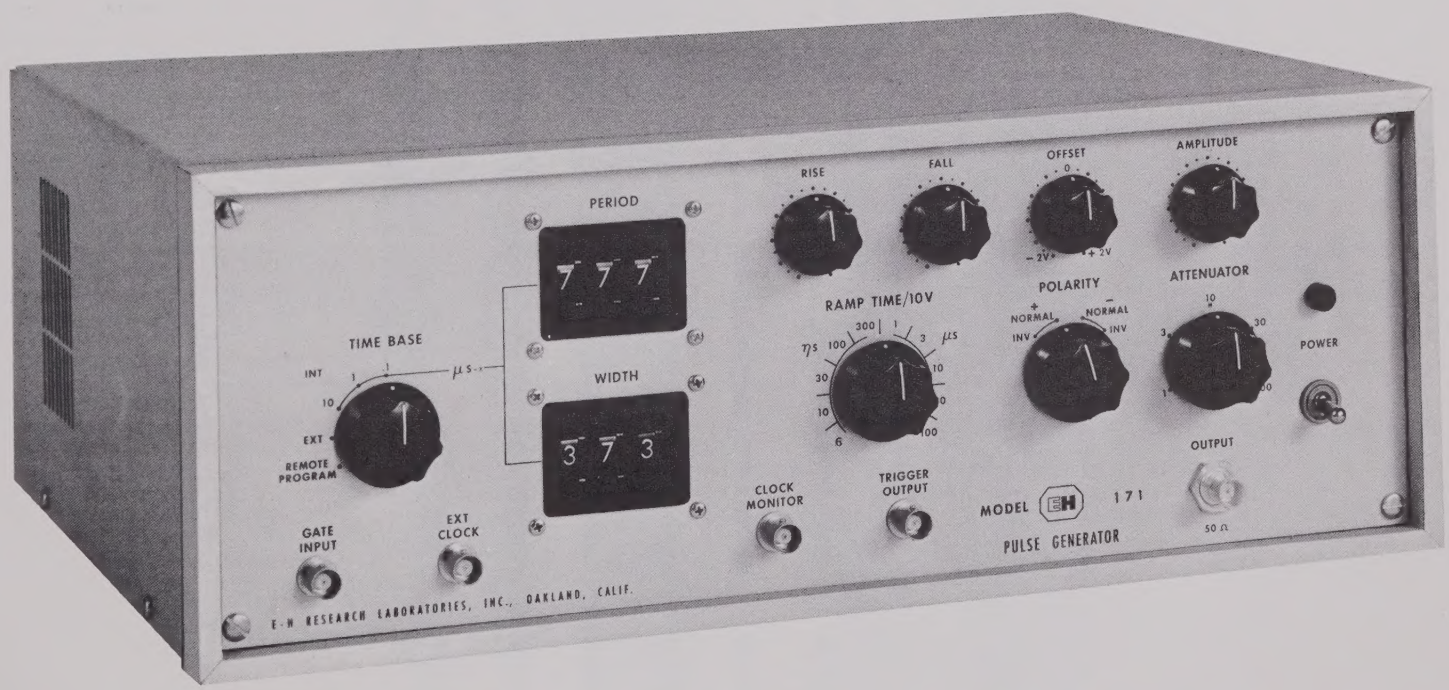


Figure 1-1 Model 171 Pulse Generator

SECTION 1
SPECIFICATIONS

1-1 GENERAL

The E-H Model 171 is a precision pulse generator that features both remote and manual digital programming operation. Pulse period and width can be programmed by computer logic, relay-contact closure, patch board, or switches for remote control. Analog programming by external resistors or potentiometers is required for remote vernier control of output-pulse risetime, falltime, baseline offset, and amplitude.

The pulse repetition rate is derived from stable, crystal-controlled time bases of 10, 1.0, or 0.1 microseconds. Pulse period is switch selected from 2 to 999 times the time base, and pulse width is selected from 1 to 998 times the time base. Both are digitally controlled, by either front panel selectors or by remote logic circuits. Pulse risetimes and falltimes are linear and independently adjustable within any selected range between 6 nanoseconds and 100 microseconds, with a maximum of 3 to 1 between risetime and falltime. Ranges are not remotely selectable. Output pulse waveforms may be inverted so that the amplitude control sets the baseline from 3 volts to 10 volts. The pulse baseline can be adjusted from the zero reference to ±2 volts.

A separate trigger output provides signals for triggering oscilloscopes, additional pulse generators, or other test instruments. Model 171 may be externally driven at any repetition rate up to 10 megahertz, to provide the countdown clock, or it can be gated with an external signal. A clock-monitor output permits accurate external measurement of, and synchronization with, the internal crystal-controlled clock. The Model 171 is packaged with a durable heavy duty metal frame suitable for either rack or cabinet mounting.

1-2 SPECIFICATIONS

PULSE REPETITION RATE: 100.1 hertz to 5.0 megahertz. Repetition rate is de-

1-2 Continued

rived from three time-base periods of 10, 1, or 0.1 microsecond generated by internal crystal-controlled clocks. Stability is better than one part in 10^{-4} including initial setting and long-term drift under normal operating conditions.

EXTERNAL CLOCK DRIVE: Zero to 10 megahertz. Required external drive signal is +1 volt peak (minimum) to +10 volts peak (maximum). There are no waveform requirements; the Model 171 may be driven with a sine wave signal. Input impedance is 470 ohms (variable from 200 nanoseconds to 9.99 milliseconds). Pulse period is from 2 to 999 times the basic clock period (0.1, 1, or 10 microseconds).

PULSE PERIOD: On internal clock, accuracy is 0.01%. May be programmed either remotely, or by digital setting on front panel.

PULSE WIDTH: Variable from 100 nanoseconds to 9.98 milliseconds. Pulse width is from 1 to 998 times the basic clock period (0.1, 1, or 10 microseconds). On internal clock, accuracy is 0.01% ±10 nanoseconds. May be programmed either remotely, or by digital setting on front panel. Width may be set up to one count less than the period.

DUTY FACTOR: No limit, except that width control must be set at least one count less than the period control. At minimum pulse period (maximum frequency), duty factor limit is therefore 50%. At maximum period, duty factor is greater than 99%.

REMOTE PROGRAM: 1-2-4-8 complementary logic. Programming is either by contact closure or by zero and ±5 volt logic levels (+15 volts maximum allowable). The logic signals are inserted at a rear panel connector. Fast acting logic may be applied for response within the time base interval. Input impedance approximately 500 ohms.

GATE: Short circuit across the GATE

1-2 Continued

input connector blocks output pulse train. Either contact closure or zero and +5 volt logic levels may be used (+15 volts maximum). Input impedance ≈ 500 ohms.

CLOCK MONITOR: Delivers pulses of +1.5 volts into 50 ohms. Pulses are coincident with the clock oscillator and are approximately 50 nanoseconds in width. Output impedance ≈ 50 ohms. Pulses appear at the clock monitor regardless of whether the output pulse has been gated off or not.

BASELINE OFFSET: ±2 volts, adjustable, either polarity. The pulse train baseline may be adjusted from zero up to ±2 volts. The algebraic sum of peak amplitude and offset voltage is limited to ±10 volts. With the attenuator in the 1:1 position, the output pulses may be inverted so that the baseline is variable from ±3 volts to ±10 volts depending on amplitude setting; in this condition, the pulse baseline level and the pulse peak are also adjustable ±2 volts with the offset control. The ATTENUATOR attenuates both the output pulse and the baseline offset.

External bias may be applied, provided that the sum of the bias, pulse, and offset voltages do not exceed ±10 volts peak, as referred to zero, with the ATTENUATOR set to 1:1, or proportionally lower on other ATTENUATOR settings.

TRIGGER OUTPUT: -1 volt into 50 ohms. The trigger pulse is approximately coincident with the leading edge of the output pulse and is 10 nanoseconds in width.

OUTPUT PULSE AMPLITUDE: ±30 millivolts, to ±10 volts, into 50 ohms; variable by step attenuator and vernier AMPLITUDE control. Output impedance ≈ 50 ohms.

RISE AND FALL TIMES (10 to 90%): 6 nanoseconds to 100 microseconds by coarse selector (6/10/30/100/300 nanoseconds, 1/3/10/30/100 microseconds), and independent vernier controls for rise and fall. The output pulse rises and falls at essentially a constant dv/dt, regardless of amplitude variations, except at very fast risetimes. (At 5 volts output, the fastest risetime is less than 5 nanoseconds.) Linearity better than ±5% from 10 nanoseconds to 300 nanoseconds, ±3% from 300 nanoseconds to 3 milliseconds.

1-2 Continued

WAVEFORM DISTORTION: Pulse top distortion is less than 5% peak-to-peak, including overshoot, ringing, droop and all pulse top anomalies for all amplitude conditions. Baseline distortion is less than 5% peak-to-peak, except less than 8% peak-to-peak with attenuator at 100:1 position.

REMOTE PULSE-PARAMETER PROGRAMMING: Analog programming for the equivalent of FINE (vernier) control of output-pulse rise/fall times, baseline offset, and amplitude is available with either external resistors or external potentiometers, using a rear-panel connector provided for interconnection with the external control elements. Polarity may be inverted by external contact closures.

OUTPUT TERMINATING IMPEDANCE: 50 ohms. The Model 171 operates as a current source, with a dc-coupled output. The output impedance is approximately 50 ohms during the transition times of fast rise and fall time pulses.

POWER REQUIREMENTS: 105/125 vac, 50/60 hertz, 150 volt-amperes (234 volt service available at no extra cost).

DIMENSIONS:

Cabinet Mount:	6" high, 17" wide, 12" deep.
Rack Mount:	7" high, 19" wide, 12" deep.
Weight:	29 lbs. net; 37 lbs. packed; 45 lbs. packed for export.

E-H MODEL ZT PULSE TRANSFORMER: This accessory unit is a nanosecond transformer for impedance matching or inversion. Impedances available are 50, 93, 125, 185, and 200 ohms in any combination, input to output, with or without inversion.

E-H MODEL CX-5 CABLE SET: This set consists of two 5-foot cables, RG-58A/U, with 50-ohm characteristic impedance. This set is supplied with BNC connectors.

ADDITIONAL ACCESSORIES: The E-H BNC series accessories are compatible with both the E-H Model 171 and other instruments having BNC connectors. For further accessory information, refer to the data at the back of this manual.

SECTION 2
OPERATING INFORMATION

2-1 UNPACKING

Immediately after unpacking the instrument, carefully inspect and evaluate the condition of the shipping container and instrument for evidence of damage that might have occurred during shipment or handling. If damage is noted, the responsible carrier or agency should be promptly notified.

2-2 234 VOLT OPERATION

The internal power supply of the Model 171 is normally connected for 117 vac operation. For 234 volt operation, reconnect the transformer primary and change fuse F101.

2-3 OUTPUT IMPEDANCE

The Model 171 is basically a current source. Output impedance is approximately 50 ohms at high frequencies in the 1:1 attenuator position. The attenuator is back-matched to approximately 50 ohms above attenuations of 10:1. The output is short and open-circuit protected, but is not intended to operate in the open-circuit condition for extended periods. The output is designed to operate into a 50-ohm resistive load. Any other load impedance will cause some pulse distortion. Loads with appreciable capacitive or inductive components will have an appreciable effect on the leading and trailing edges of the pulse. Use the E-H Model ZT Pulse Transformer to match the Model 171 output to other impedances, where characteristics of ZT pulse transformer will permit.

2-4 CABLES, CONNECTORS, AND ATTENUATORS

The sharp risetime of the 171 has appreciable frequency components up to about 200 megahertz. If any of these high frequency components are attenuated through the use of connectors, cables, or attenuators, that do not have a flat frequency response in excess of these frequencies, degradation of the pulse

2-4 Continued

risetime will result. Mismatch effects can also degrade the pulse waveform: consequently, consideration and care must be taken to preserve the quality of the Model 171 pulse output when coupling it to the system or device under test.

Some of the precautions to observe in coupling the pulse outputs of this instrument are:

(1) Always terminate the output of the Model 171 in a 50-ohm resistive load.

(2) If the input impedance of the device or system under test is other than 50 ohms, use an impedance matching device so that mismatch effects will not degrade the pulse waveform.

(3) Make sure that all connectors, attenuators, and cables are of proper impedance and have a flat frequency response in excess of 200 megahertz. Use only high quality 50-ohm coaxial cable, such as RG-58C/U or RG-213/U with properly matched connectors.

2-5 OPERATING CONTROLS AND CONNECTORS

a. POWER. Controls ac power. To operate, connect the line cord to a 117 volt alternating current, 50/60 hertz power source. Set the POWER switch to the ON position, the fan will be energized, POWER indicator light will glow.

b. TIME BASE. Selects either the fundamental time base from which the output pulse period and width are derived. Time base selections are: 10, 1.0, and 0.1 microseconds from internal crystal-controlled clock; external drive of 0 to 10 megahertz; and remote program for digital BCD-logic control.

c. PERIOD. Selects pulse period over the range from 2 to 999 times the fundamental time base.

d. WIDTH. Selects pulse width over the range from 1 to 998 times the clock-pulse period.

2-5 Continued

e. RAMP RATE/10V. Selects 1 of 9 output rise and fall (voltage ramp) time ranges (6 nanoseconds to 300 microseconds). Ramp rate ranges are: 6/10/30/100/300 nanoseconds; 1/3/10/30/100. Rise and fall times are individually adjustable with the RISE and FALL controls, with a ratio from 1:1 to 3:1 between rise and fall times possible.

f. RISE. Varies output pulse rise time (voltage ramp) within the range selected by the RAMP RATE/10V control.

g. FALL. Varies output pulse fall time (voltage ramp) within the range selected by the RAMP RATE/10V control.

h. POLARITY. Selects the output pulse polarity from one of four possible mode (+INV, +NORMAL, -NORMAL, and -INV). For further details, see Section 2-6a.

i. OFFSET. Adjusts the output pulse baseline voltage level. If the ATTENUATOR switch is set to 1, the baseline offset adjustment is continued out between +2 volts to -2 volts, regardless of output pulse polarity. For further details, see Section 2-6b.

j. ATTENUATOR. Selects one of four resistive attenuation ratios or a straight-through connection. Available attenuation ratios are 1:1, 3:1, 10:1, 30:1, and 100:1.

k. AMPLITUDE. Varies the output pulse amplitude. If the ATTENUATOR switch is set to 1, the AMPLITUDE control provides continuous output pulse amplitude adjustment from ±3 to ±10 volts.

l. OUTPUT CONNECTOR (BNC). The OUTPUT connector supplies the output pulse train to an external 50-ohm load. When the ATTENUATOR switch is set to 1, the OUTPUT appears to the load as a current source. The Model 171 is completely short and open circuit protected, but it is not intended for operation in the extended periods.

m. TRIGGER OUTPUT CONNECTOR. Provides a -1 volt pulse into 50 ohms for driving or synchronizing other instruments.

n. CLOCK MONITOR CONNECTOR. Provides a +1.5 volt pulse into 50 ohms for synchronization of or measurement by other instruments. The monitor pulse occurs in coincidence with the internal clock at the time base frequency and is about 50 nanoseconds in width.

o. EXT. CLOCK CONNECTOR. Application of a +1 to +10 volt signal (peak), at any

2-5 Continued

frequency up to 10 megahertz, provides the time base. To operate, set the TIME BASE control to EXT, and connect the input signal to the EXT. CLOCK connector. The input signal may be a pulse or a sine wave. Input impedance 470 ohm.

p. GATE INPUT CONNECTOR. Application of a short circuit inhibits the OUTPUT 50Ω pulse train. Removing the short circuit or returning to +5 volts dc level re-enables the pulse output.

2-6 OPERATING NOTES

a. DUTY FACTOR LIMITATION. The duty factor is limited at high repetition rates by the fact that the minimum pulse width is 100 nanoseconds (1 x 0.1 microsecond). Thus, when the output pulse period is minimum (200 nanoseconds at 5.0 megahertz), and the width is minimum, the maximum duty factor is 50%. The effective duty factor may be increased by inverting the pulse polarity (e.g., from +NORMAL to +INV) and increasing the period. See Figure 2-1.

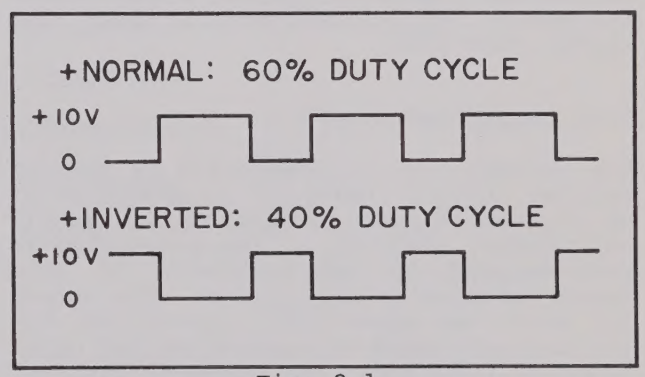


Fig. 2-1

b. OFFSET. The OFFSET control, located above the POLARITY selector switch, provides baseline offset of ±2 volts. Maximum output amplitude of the Model 171 is ±10 volts.

The offset operates by the summing currents from a fixed, negative source and a variable positive source. The fixed negative current is -40 milliamperes. For +2 volts offset, the positive source provides +80 milliamperes more than required for pulse operation. For -2 volts offset it provides zero current.

c. RAMP RATE OPERATION as ramp rate is increased, also increase the pulse width and increase the pulse period as necessary. Pulse width should be greater than the risetime, or the output pulse amplitude and waveform tend to degenerate.

2-6 Continued

d. GATE INPUT OPERATION. The gate circuit blocks the output pulse train while leaving the time base clock undisturbed. If the gate signal is repetitive, the output signal of the Model 171 will be a series of pulse bursts. The duration of each burst is determined by the time the gate signal is off. The frequency of the pulse burst is determined by the gate pulse period.

e. REMOTE PROGRAMMING.

(1) GENERAL. The Model 171 Pulse Generator may be controlled remotely through the two programming connectors located on the rear panel of the instrument. The TIME BASE (internal clocks at 10 MHz, 1 MHz, and 100 KHz), pulse PERIOD (frequency), and pulse WIDTH are digitally programmed through connector J103. The output parameter controls--RISE, FALL, baseline OFFSET, AMPLITUDE, and POLARITY--are through connector J104 (for more detailed drawings refer to Schematic No. 7).

(2) TIMING CIRCUIT REMOTE PROGRAMMING. For remote control of the time base, turn the front panel TIME BASE switch to the REMOTE PROGRAM position. Choose the internal-clock time base required for proper pulse repetition rate for a given program by shorting one of 13 through 16 on connector J103 to ground. (See Figure 2-2.)

(3) PULSE PERIOD AND WIDTH PROGRAMMING. Pulse WIDTH and PERIOD are programmed with three-digit binary-coded decimal (BCD) complementary logic. Each digit (units, 10's, and 100's) has a four

Pin Number	Clock
13	External Clock
14	10 µsec (100 KHz)
15	1 µsec (1 MHz)
16	0.1 µsec (10 MHz)

Fig. 2-2

2-6 Continued

line, 1-2-4-8 logic assigned to it which is brought out to the rear panel through connector J103. Program the pulse period and width by shorting to ground the pins that complement the program parameter. For a sample period program, refer to Drawing Schematic No. 7. Input impedance ≃ 1 kilohm.

CAUTION

The maximum allowable positive voltage on each control line is +15 volts. To avoid possible damage to the instrument, limit the applied voltage to between +5 and +15 volts.

(4) OUTPUT PARAMETER REMOTE PROGRAM. The vernier controls for AMPLITUDE, RISEtime, FALLtime, and baseline OFFSET are programmed with external potentiometer or voltage divider circuits. Program the output pulse polarity by shorting the proper pins together on connector J104. For internal operation, the programming connector must be replaced in J104 before normal operation may be obtained. A sample circuit is diagrammed in Drawing Schematic No. 7.

SECTION 3
THEORY OF OPERATION

3-1 GENERAL

The E-H Model 171 electrically consists of chassis-mounted assemblies and components that are discussed, by drawing, in the following order: Block Diagram, Master Schematic, Clock Schematic, Preset Decade Schematic, Gate Schematic, Output Circuit Schematic, and Power Supply Schematic.

3-2 BLOCK DIAGRAM

As shown in the Block Diagram, the EXT. CLOCK input (positive 1 volt pulses) drives the clock circuit from an external source. A short across the GATE INPUT inhibits the gate circuit from sending "start" pulses to the output circuit.

The front-panel TIME BASE control selects either one of three internally-generated time bases or the externally-supplied EXT. CLOCK signal. The output from the clock circuit is connected to both the first preset decade and the gate circuits. A fixed, 20 nanosecond delay is provided in the clock-signal path to the preset decade. The delayed clock signal initiates pulse-period and pulse-width formation of the OUTPUT 50Ω. The fundamental time base is preselected, but the pulse period can be precisely selected by means of digital programming, either locally or remotely. The preset decades provide S and S' signals to the gate circuit, initiating output-pulse start and stop signals. These start and stop signals are synchronized (locked) at the clock-signal frequency by coincidence-gating that occurs in the gate circuit. The time between the S and S' signals determines the time between the start and stop signals, which corresponds to the duration of the OUTPUT 50Ω pulse from the output circuit. The output circuit functions as a two-input, bistable circuit that permits extremely fast changes in operating state and output waveform.

The output circuit has several current amplifier stages that provide power gain to drive an output-current summation circuit. By adding current from three

3-2 Continued

sources, the summation stage provides up to 10 volt pulses in any of four operating modes. The output pulses can be either positive or negative, and either normal or inverted. Pulse amplitude is adjustable and baseline offset is variable up to two volts, either polarity.

An output attenuator, in conjunction with the AMPLITUDE control, provides 5 switch-selected attenuation ratios of 1:1, 2:1, 4:1, 8:1, and 16:1. Output amplitude is therefore continuously variable from about 0 volts up to ±10 volts. The pulses output signal appears at the OUTPUT 50Ω connector. This output appears to the load as a current source when the ATTENUATOR selector is set to 1 and the terminating impedance is 50 ohms.

A CLOCK MONITOR output permits either synchronization of, or measurement by, external instruments. The monitor-output pulses occur in coincidence with the clock signal, and are about 50 nanoseconds in duration, with an amplitude of +1.5 volts into a 50-ohm load. A TRIGGER OUTPUT from the gate circuit has a leading edge that is approximately coincident with the OUTPUT 50Ω pulse. The trigger pulse duration is 10 nanoseconds; amplitude is -1 volt into a 50-ohm load.

Either local or remote programming of most output-pulse parameters is possible. Analog programming determines output pulse risetime, falltime, baseline offset, and amplitude, within applicable ranges selected. Switching circuits determine output-pulse time base and polarity. Digital programming determines output-pulse period and width. For maximum flexibility, all of these output-pulse parameters can be remotely controlled.

3-3 MASTER SCHEMATIC

Principal assemblies and components mounted on the pulse generator are the clock circuit board, preset decade circuit boards, gate circuit board, output

3-3 Continued

board, power supply, and front-panel controls and connectors. The attenuator assembly is also mounted on the front panel. Portions of various circuits are also located on the chassis along with interconnecting wiring for power and signal distribution. An ac power receptacle, fuseholder, and cooling fan are located on the rear panel. A removable cover permits ready access to the interior of the instrument.

3-4 CLOCK BOARD SCHEMATIC

The clock circuit determines the fundamental time base and thus the clock-pulse period. Three crystal-controlled time-base signals are generated, one of which can be selected as the clock-pulse output. Alternatively, an external-clock signal can also be applied, to determine the clock-pulse period.

Crystal-controlled oscillator Q1 and Q2 operates at a frequency of 10 megahertz. Crystal Y1 determines the oscillator frequency, which may be adjusted over a narrow range by trimmer capacitor C2. Capacitor C4 and inductor L1 form a fixed-tuned, parallel-resonant circuit, which serves as the collector load for stage Q2. Bypass capacitor C5 shunts high-frequency signals to ground, tending to eliminate any oscillator signal that might otherwise appear on the +15 volt supply line.

The 10 megahertz sine wave signal from the collector of Q2 is applied to the base of buffer-amplifier Q10. A control signal from TIME BASE switch S202 determines Q10 operating state, which is either in the normal, conducting condition or in the cut-off condition. When switch S202 is set to the 0.1 µs position a dc-ground (control signal) is applied through terminal H to the diode CR4 anode. This dc-ground causes diode CR4 to stop conducting. The dc-bias voltage developed across resistor R50 becomes more negative, thus decreasing the positive dc-bias voltage at the base of Q10. Buffer-amplifier Q10 thus is placed in its normal operating condition. When switch S202 is set to any position other than 0.1 µs, the dc-ground is absent from terminal H. With the dc-ground signal no longer applied, diode CR4 conducts in the forward direction and bias voltage at the base of Q10 becomes more positive. Buffer-amplifier Q10 thus is placed in a cut-off condition and the 10-megahertz oscillator signal is blocked by Q10.

Crystal-controlled oscillator Q3 and Q4 operates at a frequency of 1 megahertz

3-4 Continued

and is functionally similar to oscillator Q1 and Q2. Crystal Y2 determines the oscillator frequency, which may be adjusted over a narrow range by trimmer capacitor C8. The 1 megahertz sine wave signal from the collector of Q4 is applied to buffer-amplifier Q11, which is controlled by TIME BASE switch S202. The buffer-amplifier passes the 1 megahertz signal only when switch S202 is set to the 1 µs position.

Crystal-controlled oscillator, Q5 and Q6, operates at a frequency of 100 kilohertz and is functionally similar to oscillator Q1 and Q2. Crystal Y3 determines the oscillator frequency, which may be adjusted over a narrow range by the trimmer capacitor, C12. The 100 kilohertz sine wave signal from the collector of Q6 is converted to a square wave by the action of tunnel diode CR1, and is applied through inverter-amplifier Q7 to buffer-amplifier Q12, which is controlled by TIME BASE switch S202. The buffer-amplifier passes the 100 kilohertz signal only when switch S202 is set to its 10 µs position.

The external-clock circuit includes tunnel-diode amplifier CR2, inverter-amplifier Q8, and buffer-amplifier Q9. External-clock signals applied at EXT. CLOCK connector J201 are direct-coupled through terminal A to amplifier CR2, which drives the inverter amplifier, Q8. Amplifier stages CR2 and Q8 provide sufficient gain for input signals as low as +1 volt peak-to-peak, with a maximum of +10 volts peak-to-peak permissable. The external-clock signal from the collector of Q8 is applied to buffer-amplifier Q9, which is controlled by TIME BASE switch S202. The buffer-amplifier passes the external-clock signal only when switch S202 is set in the EXT. position.

The buffer-amplifier collectors are connected in parallel, having a common output which appears across load resistor R58 and peaking-coil L5. Clamp diode CR7 limits negative-going peaks of the clock signal. The positive-going peaks of the clock signal are zener-diode coupled to the base of Q13, part of switching-amplifier Q13 and Q14. The Q13 collector is direct-coupled to terminal R as the clock signal. A complimentary signal from the Q14 collector is capacitor-coupled to terminal V, thence to front-panel connector J202, as the CLOCK MONITOR.

A high-frequency noise filer is connected at the +15 volt supply input, terminal 5. The filter consists of inductor L4 and capacitors C12 and C20.

3-5 PRESET DECADE SCHEMATIC

Three preset decade P.C. boards are used in the E-H Model 171. One preset decade functions as a hundreds counter, one as a tens counter, and one as a units counter. Since the circuits of the preset decade counters are functionally similar, a single discussion that is applicable to all three is given.

The preset decade counter has four bistable, nonsaturated-switch stages, which operate as transistorized Eccles-Jordan multivibrators or flip-flops (FF). These FF stages are Q3 and Q4 (FF1), Q7 and Q8 (FF2), Q11 and Q12 (FF4), and Q15 and Q16 (FF8). Inter-stage ac coupling is accomplished through buffer-amplifiers Q2, Q6, Q10, and Q14. The final output is taken directly from FF Q15 and Q16. Additional outputs for encoding are taken from FF1 through FF8 via emitter-followers Q5, Q9, Q13, and Q17, respectively.

The four, serial FF stages (FF1 through FF8) function as a decimal counter. Decimal counting is accomplished by short-counting, thus eliminating 6 of the possible 16 counts available in the unmodified four-stage counter. One the tenth trigger-input pulse, the counter is cleared back to the zero-count condition. The short-count feedback loop is from the FF8 (Q15 and Q16) output to the FF2 (Q7 and Q8) input. A forward-feed path (from buffer-amplifier Q6 output to the FF8 input) presets FF8. Trigger-input pulses applied to buffer-amplifier Q2 are thus counted in 1, 2, 4, 8 sequence by the FF stages, which reset to the zero condition at the tenth trigger-input pulse. The counter is also reset to its zero condition by a pulse that is applied through emitter-follower Q1 to the input of each FF stage. All four FF stages are simultaneously reset by the reset input.

The decade counter, operating in conjunction with two paralled encoders, accomplishes decimal to binary-coded-decimal (BCD) conversion. One encoder is controlled by a PERIOD thumbwheel switch, which is located on the front panel. The other encoder is controlled by a WIDTH thumbwheel switch, also located on the front panel. The PERIOD encoder consists of four OR gates (diodes CR14 and CR16, CR20 and CR22, CR26 and CR28, and CR32 and CR34), and an AND gate (diodes CR15, CR21, CR27, and CR33). The WIDTH encoder also consists of four OR gates (diodes CR17 and CR19, CR23 and CR25, CR29 and CR31, and CR35 and CR37) and an AND gate (diodes CR18, CR24, CR30, and CR36).

Each encoder in the preset decade counter handles one decimal digit (0 to 9) at a time. Since there are three preset decade counters, three decimal digits for both PERIOD and WIDTH control are provided. The PERIOD BCD signal from the AND gate is applied to the base of emitter-follower Q18, with the S output appearing at terminal V. The WIDTH BCD signal from the AND gate is applied to emitter-follower stage Q19 with the S' output appearing at Terminal T. Both the S and S' signals are derived from various decade-counter and front-panel switch (or remote equivalent) conditions. The three preset decade counters together provide three-digit BCD S(PERIOD) and S'(WIDTH) signals.

3-6 GATE SCHEMATIC

The gate P.C. board provides output-pulse start and stop signals, preset decade reset-input pulse signals, and the E-H Model 171 TRIGGER OUTPUT signal. For purpose of discussion, the gate board is functionally divided into trigger circuits, start curcuits, and stop circuits.

a. Trigger Circuit. The clock signal from the clock circuit is applied to direct-coupled amplifiers Q17 and Q18, which provide current gain for the clock pulse. The output of emitter-follower Q18 is simultaneously applied to diode CR4 of the start-circuit AND gate, diode CR9 of the stop-circuit AND gate, and diode CR13 of trigger-circuit AND gate CR13 and CR14. When both a start pulse and a clock pulse are coincident at AND gate CR13 and CR14, amplifier Q19 and emitter-follower Q20 produces a driving pulse. A dc-coupled signal appears at terminal C as the reset pulse and an ac-coupled signal appears at terminal D as the TRIGGER OUTPUT.

b. Start Circuit. The S signal from the preset decade is applied to emitter-follower stage Q1. The output of this stage is zener-diode coupled to current-mode switch Q2 and Q3. The current-mode switch changes operating state in synchronism with the S signal. Two complimentary outputs occur. The output from the Q3 collector is applied through emitter-follower Q21 to diode CR10 of the stop-circuit AND gate. The output from the Q2 collector is applied through emitter-follower Q4 to diode CR3 of the start-circuit AND gate.

When the clock, S, and enabling-gate signals are simultaneously preset at the AND gate (diodes CR2, CR3, and CR4), amplifier Q5 and emitter-follower Q6 provides an output. This output forces bistable multivibrator Q7-Q8 and Q9-Q10 into one of its two stable states, thus

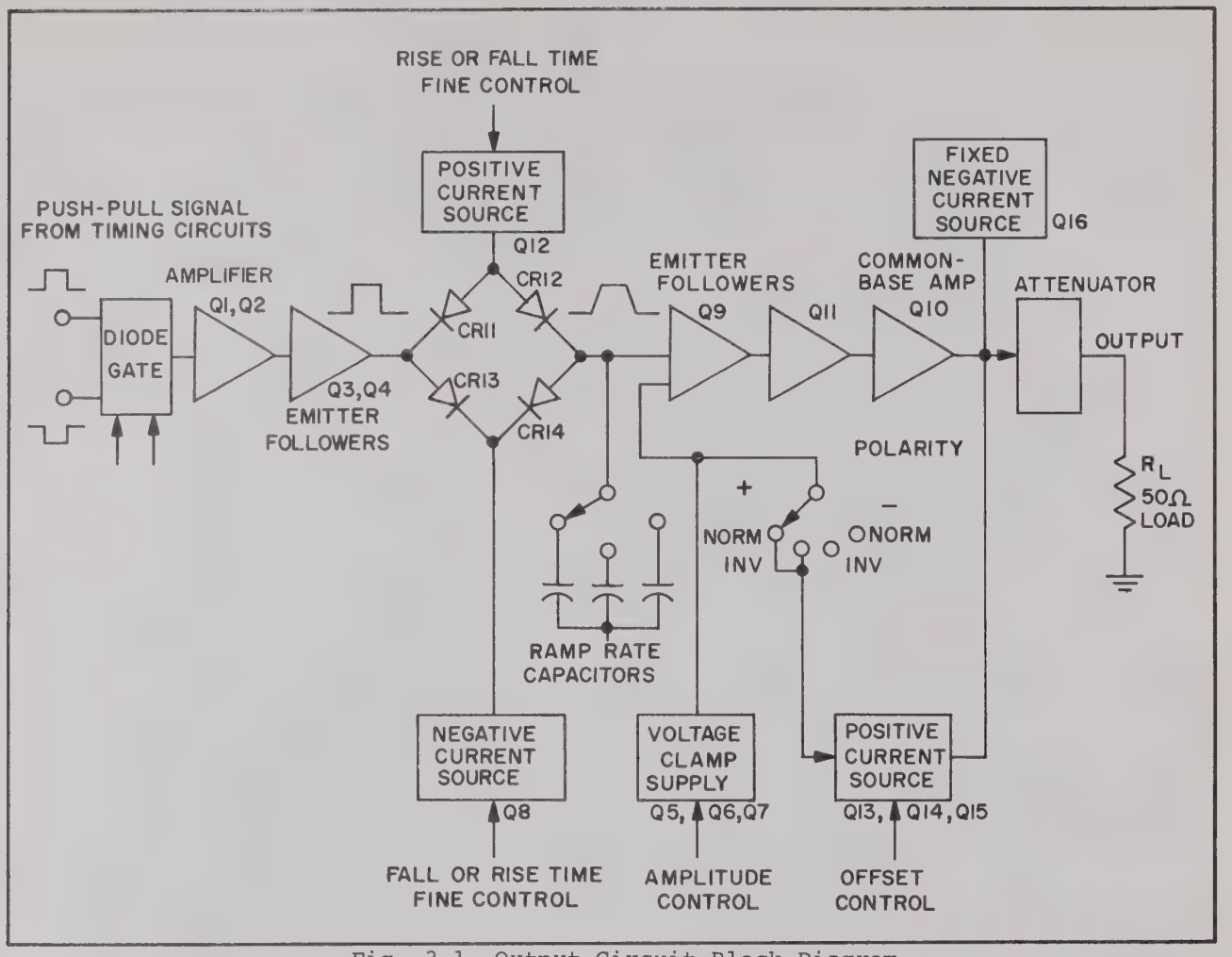


Fig. 3-1 Output Circuit Block Diagram

3-6 Continued

producing a start pulse. When either the clock or S signals terminate, stages Q5 and Q6 detect the changed input and abruptly change operating condition, removing the driving signal from the bistable multivibrator. The clock and gate signals thus serve as enabling signals to the AND gate, permitting the S signal to control the bistable multivibrator rate.

Application of an external-gate signal effectively inhibits the AND gate for the duration of the applied gate signal, and thus inhibits the Model 171 OUTPUT pulse but not the TRIGGER OUTPUT. The S and clock signals synchronize operation of both the start-circuit amplifiers Q5 and Q6, and then the stop-circuit amplifiers Q11 and Q12. When an enabling S signal is applied to the start-curcuit AND gate, the compliment of the same signal is applied to, and inhibits the stop-circuit AND gate to prevent possible triggering of the bistable multivibrator by the S' signal. Only when the S signal is absent

3-6 Continued

can the S' signal initiate a stop pulse.

c. Stop Circuit. The stop circuit is functionally similar to the start circuit, except for the input operating signals. Inputs are the S', clock, and S-compliment signals. When the inputs coincide (simultaneous occurance of S', clock, and non-S signals), the stop circuit causes bistable multivibrator Q7-Q8 and Q9-Q10 to change state, producing a stop pulse. The stop circuit consists of emitter-follower Q16, current-mode switch Q14 and Q15, emitter-follower Q13, and amplifier/emitter-follower stages.

The bistable multivibrator, Q7-Q8 and Q9-Q10, may be considered as part of both the start and stop circuits. The multivibrator operates as a non-saturated, current-mode switch, thus avoiding delay time associated with saturated operation. Small voltage swings are thus reliably switched, with minimum capacitance effects.

3-7 OUTPUT CIRCUIT SCHEMATIC

a. General. The Model 171 is designed to provide a current of as much as ±200 ma into a 50-ohm load. Output is provided in any of four different modes: +Normal, +Inverted, -Normal, and -Inverted, as shown in Figure 3-1.

If the Model 171 were to operate in only one mode, the easiest way to generate a pulse would be to switch a 200 ma current on and off. However, in order to provide four different modes of operation, the Model 171 uses a current-summing junction at the output terminal. The junction is provided with three current sources, as illustrated in Figure 3-2. In +NORMAL

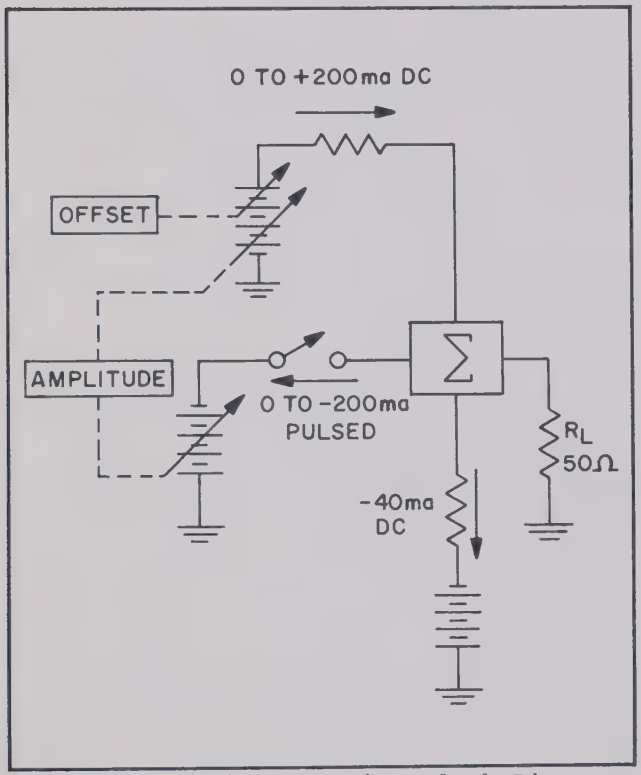


Fig. 3-2 Summing Junction Block Diagram

mode, the currents into the summing junction during the quiescent period are balanced: -40ma, +240ma, and -200ma. To provide a 10 volt +NORMAL pulse into a 50-ohm load, the -200ma. To provide a 10 volt +NORMAL pulse into a 50-ohm load, the -200ma current is shut off at t_1 and the current into the load is now +200ma. The result is a +10 volt pulse. At time t_2, the -200ma current is restored, and the current into the load is again zero. The -40ma current is constant.

Fig 3-3 summarizes the current flow into the summing junction. It is based on the assumption that offset is zero and output voltage is maximum (±10 volts). In negative modes, the positive current

3-7 Continued

source provides only the current required for the baseline offset (from 0 to +80ma). In positive modes, the positive and negative currents are equal, exclusive of baseline offset current.

b. Negative Current Pulse. The final stage of the gate circuit is a bistable multivibrator which provides a dual binary output: one output is the inverse of the other. The gate circuit outputs are fed to a diode switching network composed of diodes CR1 through CR8. Switching is accomplished by placing either forward or back bias on appropriate diodes. The diode gating network determines whether the output pulse is positive-going or negative-going.

In the +INV and -NORMAL modes, line L has a positive voltage (+15v) and line K a negative voltage (-5v). In +NORMAL and -INV modes, line L has the negative voltage, and line K the positive voltage.

In +NORMAL mode, diodes CR5 and CR6 are off due to the negative voltage on line L. CR7 and CR8 are on, due to the positive voltage on K. Thus, the signal from connector M appears across R5, and is coupled to the base of Q2. In a similar manner, CR3 and CR4 are off, due to the back bias voltage on line L. CR1 and CR2 are on, due to the positive bias on line K. The signal from connector N appears across R6, and is coupled to the base of Q1. The gating for the -INV mode is identical.

Gating for the +INV and -NORMAL is similar, except that the bias voltages on the diodes are reversed. Thus, the signal from M is coupled to Q1 and the signal from N is coupled to Q2. The diode gating network acts as a dc-actuated, DPDT switch.

The output of the binary amplifier (Q1 and Q2) is taken from the collector of Q2. In the quiescent state, transistor Q2 is either on or off, depending upon the diode switching. The collector of Q2 is connected to the base leads of both Q3 and Q4. Q3 and Q4 are complementary emitter-followers. When Q3 is on, Q4 is off, and vice versa. The voltage output from the emitters of Q3 and Q4 drives the diode bridge circuit (CR13, CR14, CR15, and CR16).

The diode bridge switches a constant current into and out of the ramp-generating capacitor, C14. The manner in which the bridge-switching action is controlled by Q3 and Q4 is best understood by considering that the collectors of the transistor Q8 and Q12 are effec-

OUTPUT PULSE MODE	OUTPUT CONDITION	SOURCE CURRENT (ma)			CURRENT SUM (ma)	OUTPUT WAVEFORM
		PULSE CURRENT	POSITIVE CURRENT	NEGATIVE CURRENT		
1 POSITIVE NORMAL	QUIESCENT	-200	+240	-40	0	+10V 0V
	PULSE +10 v	0	+240	-40	+200	
2 POSITIVE INVERTED	QUIESCENT	0	+240	-40	+200	+10V 0V
	PULSE +10 v	-200	+240	-40	0	
3 NEGATIVE NORMAL	QUIESCENT	0	+40	-40	0	0V -10V
	PULSE -10 v	-200	+40	-40	-200	
4 NEGATIVE INVERTED	QUIESCENT	-200	+40	-40	-200	0V -10V
	PULSE -10 v	0	+40	-40	0	
5 POSITIVE NORMAL	QUIESCENT	-100	+140	-40	0	+5V 0V
	PULSE +5 v	0	+140	-40	+100	
6 POSITIVE NORMAL	QUIESCENT +2v OFFSET	-100	+180	-40	+40	+5V +2V 0V
	PULSE +5 v	0	+180	-40	+140	

Fig. 3-3 Output Current Flow

3-7 Continued

tively clamped to the bridge output voltage by the bridge diodes. Thus, the collector of Q12 cannot become more negative than approximately -18 volts (according to the amplitude clamp setting). Therefore, when the bridge drive voltage rises to about -13 volts (Q3 is on) CR13 is back-biased, and the currents flow through the bridge circuit as indicated in Figure 3-4(A).

3-7 Continued

In the other state, when Q3 is off and Q4 is on, the bridge drive voltage back biases CR14 and CR15. The current flow in the bridge is indicated in Figure 3-4 (B). The voltage swing of C14 is limited to approximately 3.5 volts by the two diode clamps, CR17 and CR18. For a 10 volt pulse the voltage swing is from -14.5 volts to approximately -18 volts. The lower voltage is variable, and volt-

3-7 Continued

age on this clamp ultimately determines the amplitude of the pulse at the output. As the amplitude clamp voltage rises

3-7 Continued

toward -15 volts, the pulse amplitude decreases. In this manner, the amplitude clamp controls the voltage swing at the

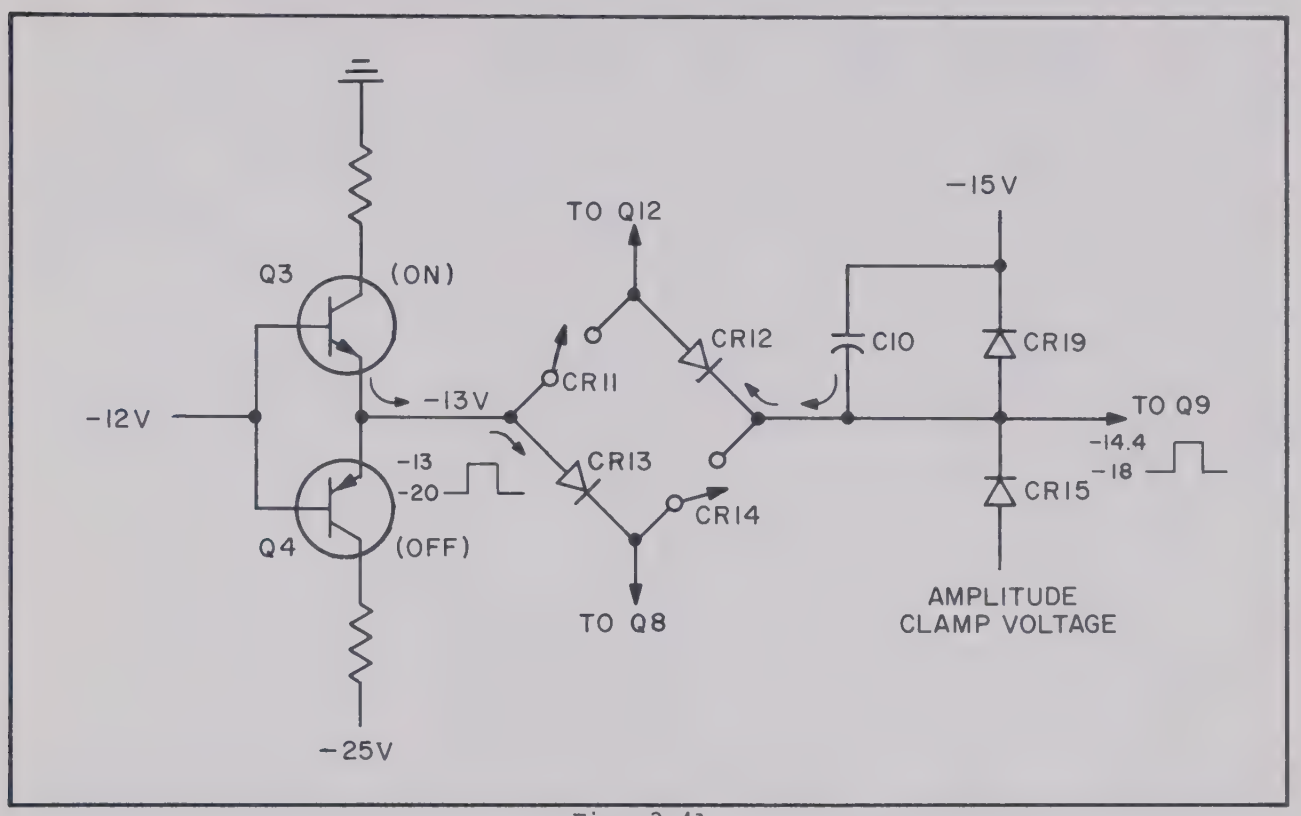


Fig. 3-4A

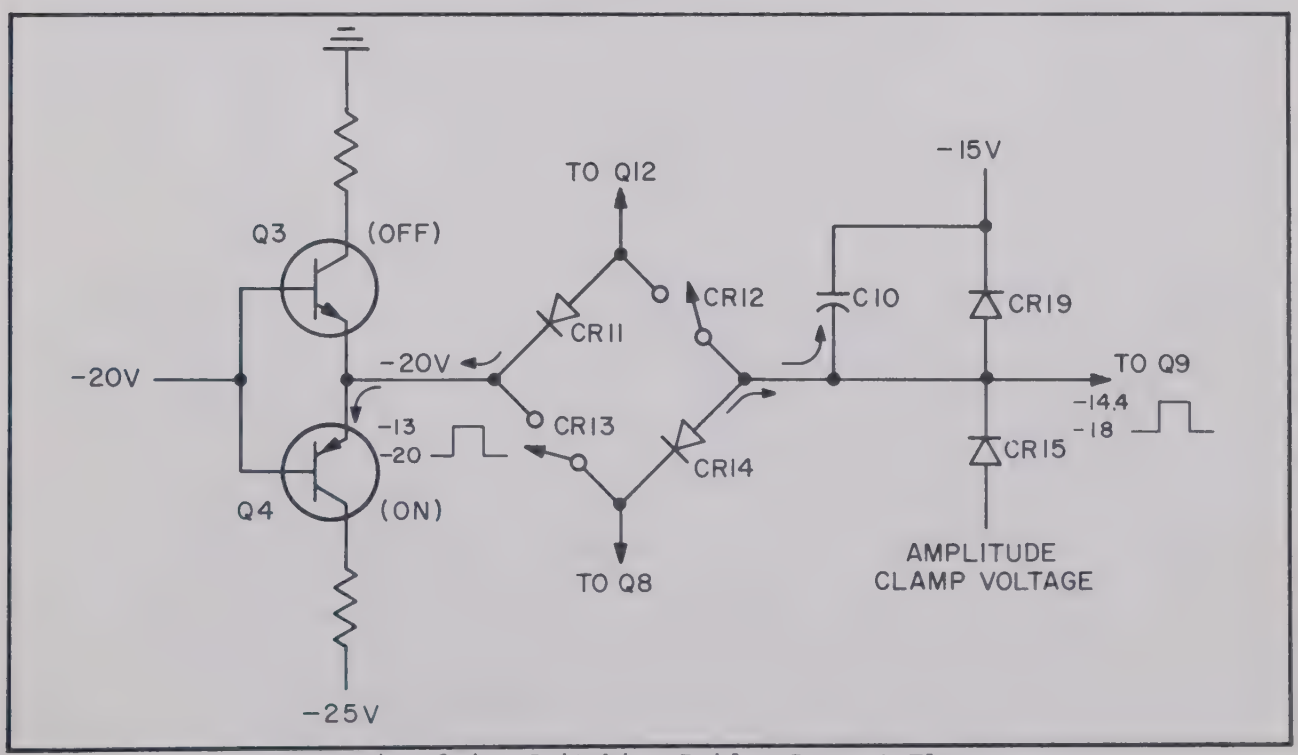


Fig. 3-4B Switching Bridge Current Flow

3-7 Continued

output of the diode bridge (the junction of diodes CR14 and CR16).

The current into and out of the bridge is supplied by two transistors, Q8 and Q12. Q8 and Q12 are always on, and if they are considered to behave as variable current control devices, then a change in their bias voltage will change the current through the bridge. The constant current flow of C14 provides a constant voltage ramp (dv/dt = I/C), where I and C are constant.

The voltage ramp drives emitter-follower Q9. This transistor has sufficient current gain to drive Q11, which in turn, drives common-base, linear current amplifier Q10. Q10 and Q11 form a complementary pair, and operate as a linear current amplifier. Linear current amplification permits the voltage ramps generated across C14 to control the current into the summing junction (terminal S on the schematic).

3-7 Continued

c. Amplitude Control. The pulse amplitude is changed by varying the amplitude clamp voltage between -16.3 and -18.5 volts. Q5, Q6, and Q7 control the amplitude clamp voltage. Q5 is an emitter-follower amplifier which has two functions: 1) to control the emitter voltage, and thus, the bias of Q9, and 2) to control the base current into Q6.

For the following discussion, consult Figures 3-5 and 3-6. The voltage at the emitter of Q5 controls the voltage at the base of Q6. The collector of Q6 is coupled to the base of Q7, and the amplitude clamp voltage is taken from the collector of Q7. A voltage change at the base of Q5 will change the amplitude

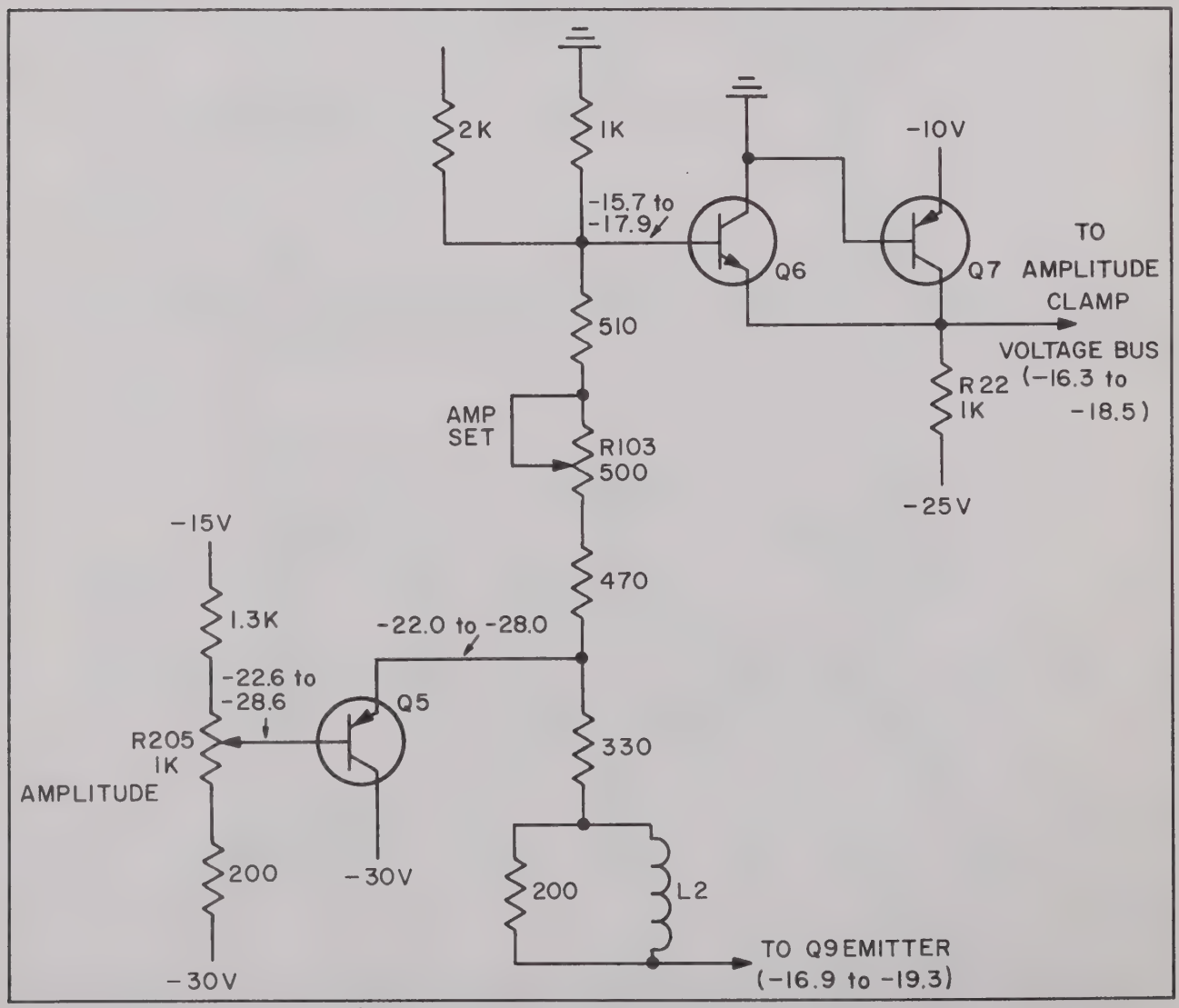


Figure 3-5 Amplitude Control Circuit

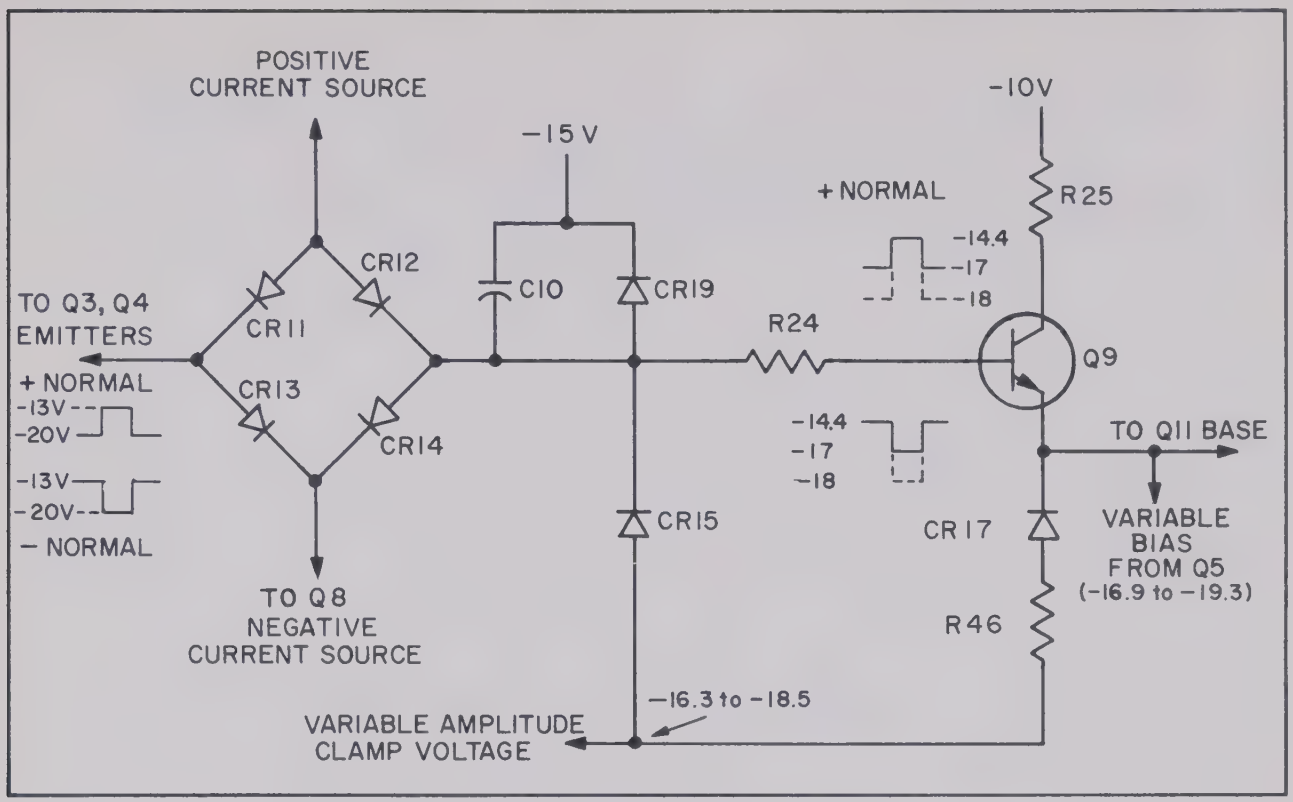


Figure 3-6 OUTPUT Amplitude Control

3-7 Continued

clamp voltage, and, in turn, the pulse amplitude.

Q6 and Q7 form a variable shunt voltage regulator. Since the base of Q6 is at a constant voltage (between -10v and -15v) any deviation of the amplitude clamp voltage will be seen by the emitter of Q6 as a bias change. The collector of Q6 will drive the base of Q7 in a manner to compensate for the voltage change across R22.

In order to decrease the pulse amplitude, the voltage of the amplitude clamp is brought closer to -15 volts. To increase the pulse amplitude, the amplitude clamp voltage is made more negative. For maximum pulse amplitude, the clamp voltage is approximately -18 volts.

d. Positive Current Source. The purpose of the positive current source is twofold. First, for positive-pulse modes only, it supplies positive current to the summing junction that is equal in magnitude to the negative pulse current. Second, for both positive and negative-pulse modes, it provides a variable current (0 to +80ma), which is added to the negative current from Q16 for baseline offset.

The positive current is supplied by a

3-7 Continued

direct coupled amplifier, Q13, Q14, and Q15. For positive pulses only, the base of Q14 is connected to the amplitude clamp voltage bus through S205 and R33. Thus, the amplitude clamp voltage controls both the negative pulse current and the positive current. The collector of Q14 drives the base of Q13; the collector of Q13, in turn, drives the base of Q15. The collector of Q15 is connected to the current summing junction through an LR network.

The second function of the positive current supply is to provide baseline offset current. Assume, for the discussion, that the Model 171 is operating in -NORMAL pulse mode. The positive source is disconnected from the amplitude clamp voltage, so that it provides only the current required for baseline offset. For zero offset, it provides +40ma. When added to the fixed -40ma current, there is no current to the load. For -2 volts offset, the positive source provides no offset current; for +2 volts offset, the positive source provides +80ma.

Associated with the positive current source are three chassis-mounted potentiometers, R111, R109, and R110 which are labeled ZERO SET, AMP SET, AND Δ0 SET, respectively. These are bias controls. The ZERO SET and Δ0 SET potentiometers

3-7 Continued

set the operating bias for Q14, as does board-mounted potentiometer R34. The AMP SET potentiometer sets the operating bias for Q6, and thus determines both the amplitude clamp voltage and the output-pulse amplitude. For negative modes, the amplitude clamp is effectively disconnected. All of these adjustments are trimmer potentiometers.

e. Fixed Negative Current Source. As shown in Fig. 3-3 there is a fixed -40ma current provided by Q16 to the current summing junction. The purpose of this source is to supply current for addition to the current from the positive source. Assuming that the algebraic sum of all other currents is zero the sum of the fixed negative (-40ma) plus the variable positive current (0 to +80ma) is the current available for baseline offset.

The base of Q16 is fixed at -15 volts, and its emitter is returned to the -25 volt supply through 1.8 kilohm (R46). The collector of Q16 is connected to the collector Q15. Both Q15 and Q16 supply current to the summing junction.

f. Output Inductance Network. There are three inductors (L5, L6, and L102) between the current summing junction and the collectors of Q15 and Q16. Their purpose is to ensure that Q15 and Q16 appear to the load as a broadband, constant-current source.

3-8 POWER SUPPLY SCHEMATIC

a. Transformer, Rectifier, and Filter. Power transformer T101 is factory-connected for service with 117 vac power lines. For 234 vac service, the two transformer-primary windings can be reconnected in series, as indicated on the power supply schematic. The power transformer also has two secondary windings. The output of one is rectified by a bridge circuit (CR101 through CR104), which supplies approximately +15 volts dc through an L-C filter (inductor L101 and capacitor C101). The other secondary winding is center tapped; its output is rectified by full-wave rectifiers CR105-CR106 and CR107-CR108. The output is filtered by capacitor C105. Fuse F101 is in series with one side of the ac power-input, which is controlled by POWER switch S201. Both POWER indicator DS201 and cooling-fan motor B101 are energized when ac power is applied to the primary windings of the power transformer.

b. Regulators. The power supply has four regulator circuits: +15 volts, -30 volts, -25 volts, and -15 volts. The +15

3-8 Continued

and -30 volt outputs are supplied from separate rectifiers and are independently regulated. The -25 volt output is derived from the regulated -30 volt output, but has a separate regulator circuit. The -15 volt output is derived, in turn, from the regulated -25 volt output; the -15 volt output also has a separate regulator, which is referenced to the regulated +15 volt output. Except the the -15 volt regulator, all regulators are referenced to chassis ground.

In the +15 volt regulator, Q101 and Q102, are connected in parallel in a series-regulator circuit. Q101 is connected to Q101 and Q102, in a Darlington-amplifier configuration and is driven by the collector of Q104. The Q104 emitter voltage is determined by reference-amplifier Q105, which is controllled by a fixed, reference voltage developed across zener diode CR110. Any change in output voltage appears as a voltage change at the base of Q104, which controls Q102 and Q103 (through Q101) to compensate for such changes. For more stable operation, the Q104 collector current is drawn from a voltage source that is fixed by zener diode CR109. The output-voltage level is adjusted by +15 V ADJ trimmer potentiometer R106.

In the -30 volt regulator, Q106 is the series regulator. Q2 in the control amplifier. Q1 is the voltage-sensing amplifier. A change in output voltage is sensed by Q1; thus causes control amplifier Q2 to change the Q106 base bias, thus varying the series resistance of Q106 so as to oppose the original change in output voltage and thus maintain a constant output voltage.

In the -25 volt regulator, Q107 is the series regulator. Q4 is the control amplifier. Q3 is the voltage-sensing amplifier. The -25 volt regulator is functionally similar to the -30 volt regulator.

In the -15 volt regulator, Q108 is the series regulator and Q5 is the voltage-sensing and control amplifier. The reference voltage at the base of Q5 is developed across resistors R15 and R16, which form a voltage divider that is connected between the -15 volt and +15 volt outputs. There is not only negative feedback from the -15 volt output, but also a reference voltage derived from the +15 volt output. A change in either the -15 or +15 volt output thus results in correction of the -15 volt output to maintain the nominal 30 volt difference between the two outputs.

SECTION 4
MAINTENANCE

4-1 GENERAL

The E-H Model 171 requires a minimum amount of maintenance; however, normal aging of electronic components may eventually cause abnormal operation. Therefore, general maintenance and trouble-shooting information is included in this section as a guide to restoring the instrument to normal operation.

4-2 ROUTINE MAINTENANCE

A regular program for maintenance and inspection every four to six months is recommended to effectively minimize the probability of equipment down time. The unit should be carefully checked in the following manner:

a. Remove the Model 171 cover panels.

b. Make a thorough inspection of all wiring and cables. Check for frayed, loose or burnt wires.

c. Check the physical integrity of all components. Look for evidence of burning or cracking, loose solder connections, leakage of insulation compound, and general physical damage.

d. Check all switches and controls for loose or broken terminals, tight or sticking shafts, etc.

e. If the internal panel surfaces and components have an excessive amount of dust or lint deposited on them, use a low pressure stream of air to remove the foreign material.

CAUTION

Do not clean the circuit boards or small internal components with a wiping cloth or solvents, since damage to the circuits may result.

f. Wipe the external instrument surfaces with a soft, damp cloth to remove dirt, fingerprints, and other foreign material.

4-2 Continued

g. Lubricate the ventilation fan by placing two drops of instrument oil on each bearing pad. Wipe any excess oil and dirt from the fan surfaces.

h. Check operation of the instrument in accordance with SECTION 4-3, PERFORMANCE VERIFICATION.

i. Replace the cover panels if all checks indicate that the instrument is operating properly.

4-3 PERFORMANCE VERIFICATION

E-H Model 171 performance can be verified by the basic procedures outlined in this section. While performing these checks, it is important that the proper test equipment be utilized to ensure accurate test results. Suggested test equipment is listed below.

a. Test Equipment.

(1) Oscilloscope: to provide the following test capabilities; sweep calibrated to approximately 1 nanosecond/centimeter, dual trace vertical amplifiers with vertical sensitivity of at least 10 millivolts/centimeter and rise-time of less than 350 picoseconds. An oscilloscope that meets these specifications is the Tektronix (TEA) Type 661 with a Type 4S1 and Type 5T1A or Type 5T3 Plug-in units. This is a sampling oscilloscope with low input impedance. For trouble-shooting, it should be used with a cathode-follower probe to provide a high input impedance. Satisfactory alternatives that might be used are the Tektronix Type 519, 561A, 546, or 567, using either a Type 3S76 or Type 3T77 Plug-in unit with the latter 3 oscilloscopes. Another alternative (for trouble-shooting), is the Tektronix Type 541 oscilloscope with Type L Plug-in unit.

(2) DC Voltmeter: that provides greater than 20k ohm/volt input impedance; accuracy and resolutation to at least 0.2%; and dc voltage scales of 0 to 30 volts. A suitable dc voltmeter is

4-3 Continued

Fluke (FLA) Model 801, 803, or 825.

(3) Pulse Generator: that provides a variable repetition rate up to approximately 10 megahertz and output pulse amplitude of at least +1.0 volts (peak-to-peak) into a 50-ohm load. A suitable pulse generator would be an E-H Model 120E (with accessory pulse inverter), E-H Model 121 (with accessory attenuator), E-H Models 122, 123A, 139B, or 171.

(4) Frequency Meter or Counter: that provides frequency measurement capability up to 10 megahertz; accuracy of at least 1 part in 10^6; and an input sensitivity of at least 1.5 volts (across 50 ohms). A suitable frequency counter would be either a Berkeley Beckman Model EPUT Counter or a Hewlett-Packard Model 5245L Electronic Counter.

NOTE

Some of the following procedures are to be done with Model 171 chassis cover removed. Arrange a fan to cool the circuit boards, thus minimizing the possibility of overheating and erratic operation. For all procedures, ac power must be applied and the POWER switch must be set to the on position.

b. Power Supply Checkout and Adjustment.

(1) Using an accurate voltmeter, measure the +15 volt regulated supply. Voltage at the output should be positive 15 ±0.15 volts. If necessary, reset +15 V ADJ potentiometer R106.

(2) Using an accurate voltmeter, measure the -30 volt regulated supply. Voltage at the output should be negative 30 ±0.7 volts.

(3) Using an accurate voltmeter, measure the -25 volt regulated supply. Voltage at the output should be negative 25 ±0.6 volts.

(4) Using an accurate voltmeter, measure the -15 volt regulated supply. Voltage at the output should be negative 15 ±0.4 volts.

(5) Using a calibrated oscilloscope, measure the ac peak-to-peak ripple on the output of each of the four regulated supplies. Ripple should be less than 10 millivolts.

(6) When feasible, vary the input ac voltage between 105 and 130 volts several times while monitoring each of the regulated-supply outputs with an accurate voltmeter. Each regulated-supply output voltage should remain within the applicable limits given in steps 4-3b (1) through 4-3b (4).

4-3 Continued

c. Time Base Checkout and Calibration.

(1) Check for the presence of a dummy plug in connector J104; install a properly-wired dummy plug if needed, (refer to Schematic No. 6).

(2) Connect an accurate frequency counter to the Model 171 CLOCK MONITOR connector, making any necessary operating adjustments.

(3) Set the Model 171 TIME BASE selector to 0.1μs.

(4) Using the frequency counter, measure the clock frequency. It should be 10 megahertz, with an accuracy of 0.01%. If necessary, adjust trimmer capacitor C2 on the clock circuit board for a 10 megahertz clock signal.

(5) Set the Model 171 TIME BASE selector to 1μs.

(6) Using the frequency counter, measure the clock frequency. It should be 1 megahertz, with an accuracy of 0.01%. If necessary, adjust trimmer capacitor C8 on the clock circuit board for a 1 megahertz clock signal.

(7) Set the Model 171 TIME BASE selector to 10μs.

(8) Using the frequency counter, measure the clock frequency. It should be 100 kilohertz, with an accuracy of 0.01%. If necessary; adjust trimmer capacitor C13 on the clock circuit board for a 100 kilohertz clock signal.

(9) Set the TIME BASE selector to EXT and apply an external-clock signal to the EXT. CLOCK connector.

(10) Using the frequency counter, measure the clock frequency. It should be the same as the EXT. CLOCK input-signal frequency, which can be measured to verify the 1:1 frequency ratio.

(11) Connect an oscilloscope to measure the CLOCK MONITOR output. The clock-signal pulses should be approximately +1.5 volts peak in amplitude (when the output is terminated in a 50-ohm load) and approximately 20 to 50 nanoseconds wide.

NOTE

If clock-monitor pulse frequency cannot be adjusted to .01% accuracy, or the shape of the pulse is grossly in error, it is possible that one or more components on the clock circuit board are out of tolerance should be replaced (refer both to SECTION 5 PARTS LIST, and to Schematic No. 1 for component values and tolerances).

d. Period and Width Checkout.

4-3 Continued

NOTE

For both the PERIOD and WIDTH front-panel controls, similar results are obtained at both the 000 and 001 settings.

(1) Using a calibrated oscilloscope with high impedance probe, observe the signal appearing at Pin F (start signal) of the gate circuit board.

(2) Measure pulse-signal period and width at various TIME BASE, PERIOD, and WIDTH, control settings, as given in Subsection 4-4. The pulse period and width measured should correspond to the values given in Subsection 4-4.

(3) Set the PERIOD control to 080, set the WIDTH control to 030, connect a calibrated oscilloscope according to step 4-3d (1), and connect an accurate voltmeter to measure the +15 volt regulator output.

CAUTION

In the following step, avoid exceeding the voltage limits given. Under no circumstances should the voltage variation exceed 15 ±1 volt.

(4) Using +15 V ADJ potentiometer R106, slowly vary the regulated voltage between +14.5 and +15.5 volts while simultaneously observing the pulse waveform displayed by the oscilloscope. Both the pulse width and period should remain constant; if observable error occurs at any voltage level within the range given, it is possible that one or more components are out of telerance and should be replaced. At the conclusion of this step, reset +15 V ADJ potentiometer R106 for a regulator output of 15 ±0.15 volts.

e. Remote Time-Programming Checkout.

(1) Connect the remote-program control to connector J103.

(2) Set the TIME BASE control to REMOTE PROGRAM

(3) Repeat steps 4-3d (1), and 4-3d (2), using the remote-program control to establish the TIME BASE, WIDTH, and PERIOD conditions given in Subsection 4-4. Measurements should agree with the values given in Subsection 4-4.

f. Gate Input Checkout.

(1) With the pulse generator operating normally and with an oscilloscope connected to observe the OUTPUT 50Ω signal (terminated in a 50-ohm load), briefly complete a short-circuiting connection at the GATE INPUT connector. The output-pulse train should cease for the time duration of the short-circuiting connection.

4-3 Continued

g. Amplitude and Offset Checkout and Calibration.

NOTE

The following steps also partially check the pulse-polarity modes, but more detailed information concerning polarity modes is given elsewhere in this manual. All of the following steps are to be done with the OUTPUT 50Ω connection terminated by a resistive 50-ohm load capable of dissipating at least 2 watts of power.

(1) Connect a calibrated oscilloscope to permit observation of the OUTPUT 50Ω signal.

(2) On the Model 171, set the AMPLITUDE control for maximum output-pulse amplitude (fully clockwise), set the ATTENUATOR control to 1, and set the POLARITY control to +INV.

(3) Set the TIME BASE, PERIOD, WIDTH, and RAMP TIME/10V controls to any convenient settings that result in a satisfactory oscilloscope display.

(4) Using the calibrated oscilloscope, measure the OUTPUT 50Ω signal amplitude. Pulse amplitude should be 10 volts, peak-to-peak. If necessary, adjust, AMP SET potentiometer R109 (on the main chassis) for an output-pulse amplitude of 10 volts, peak-to-peak.

(5) Set the POLARITY control to +NORMAL and set the OFFSET control to 0.

(6) While observing the output-pulse-train baseline displayed by the oscilloscope, slowly vary the output-pulse amplitude between 3 and 10 volts by means of the AMPLITUDE control. The baseline should remain steady, with little or no appreciable shift in its dc level. If necessary, adjust trimmer potentiometer R34 for minimum baseline shift with changes in output-pulse amplitude.

(7) With the POLARITY control set to +NORMAL, OFFSET to 0, and AMPLITUDE to maximum (fully clockwise), check that the output-pulse-train baseline is at the dc-zero level, as observed on the oscilloscope display. If necessary, adjust ZERO SET potentiometer R111 (on the main chassis) to bring the baseline dc-level to zero.

(8) Set the POLARITY control to -NORMAL, leaving the OFFSET control set to 0 and the AMPLITUDE control at maximum. The output-pulse-train baseline dc level should remain at zero. If necessary, adjust Δ0 SET potentiometer R110 (on the main chassis) to bring the base-

4-3 Continued

line dc level to zero.

(9) Repeat steps 4-3g (2) through 4-3g (8) one or more times to ensure calibration; make such additional adjustments of AMP SET potentiometer R109, trimmer potentiometer R34, ZERO SET potentiometer R111, and Δ0 SET potentiometer that are needed to optimize both the AMPLITUDE and OFFSET control calibration.

(10) With the OFFSET control set to 0, the AMPLITUDE control set to maximum (fully clockwise), the ATTENUATOR control set to 1, and the other controls set for a convenient oscilloscope presentation, check the output-pulse amplitude at POLARITY control settings of +INV, +NORMAL, -NORMAL, and -INV. Minimum output-pulse peak-to-peak amplitude should be 10 volts.

(11) Sequentially set the POLARITY control to +INV, +NORMAL, -NORMAL, and -INV, varying the OFFSET control from limit to limit at each setting of the POLARITY control. Minimum offset obtainable in each polarity mode should be two volts above and below the normal (zero) baseline, with a total offset range of at least four volts in each polarity mode.

(12) With the POLARITY control set to +NORMAL and the ATTENUATOR control set to 1, adjust the AMPLITUDE control for an output-pulse amplitude of 10 volts, as measured with a calibrated oscilloscope. Check the output-pulse amplitudes at ATTENUATOR control settings of 1 (reference amplitude), 3, 10, 30, and 100. Output-pulse amplitude should decrease in proportion to increases in the ATTENUATOR setting; measured attenuation ratios should be within ±10% of 3:1, 10:1, 30:1, and 100:1.

h. Ramp Time/10V Checkout.

NOTE

In the following steps, the combined risetime and ralltime of the output pulse must be less than the selected pulse width to prevent degradation of the pulse waveform. The selected RAMP TIME/10V range must be less than the selected pulse width for satisfactory performance. As RAMP TIME/10V range settings are increased, the pulse WIDTH and/or TIME BASE settings must be increased.

(1) Set the ATTENUATOR control to 1, POLARITY to +NORMAL, OFFSET to 0, RAMP TIME/10V to 5/10, RISE to minimum (fully counterclockwise), and FALL to minimum (fully counterclockwise); set the TIME BASE, PERIOD and WIDTH for a convenient oscillosscope presentation.

(2) Using a calibrated oscilloscope, measure the risetime and falltime of the output-pulse leading and training edges, respectively. Time between the 10% and 90% points should be 6 nanoseconds or less for both the leading and trailing edges of the output pulse.

(3) At each setting of the RAMP RATE/10V control, slowly vary both the RISE and FALL controls from limit to limit. Measured output-pulse risetime and falltime should include the selected RAMP RATE/10V range, with overlap to adjacent ranges.

(4) Using the oscilloscope vertical gain controls, normalize the 10 volt output pulse to obtain an 8 cm peak-to peak display.

(5) At the lowest RAMP RATE/10V range setting, use the oscilloscope horizontal gain and positioning controls to locate the pulse-waveform leading edge so that it passes through the corners of an arbitrary 6-by-6 cm square at the center of the display. (this places the pulse-amplitude 12.5% and 87.5 points at opposing corners of the square). Measure ramp linearity as the maximum vertical deviation from the ideal corner-to-corner straight line, expressed as a percentage of the full 8 cm amplitude. Maximum non-linearity should be 5% or less.

(6) Repeat step 4-3h (5) for each remaining RAMP RATE/10V range setting. Maximum non-linearity should be 5% for ramp times from 10 to 300 nanoseconds, and 3% for ramp times from 300 nanoseconds to 100 microseconds.

(7) Repeat steps 4-3h (5) and (6) for the pulse-waveform trailing edge. Maximum non=linearity should be 5% for ramp times from 10 to 300 nanoseconds, and 3% for ramp times from 300 nanoseconds to 100 microseconds.

i. Trigger Output Checkout.

(1) Connect a 50-ohm load to the TRIGGER OUTPUT connector, then connect a calibrated oscilloscope to monitor the trigger waveform.

(2) Set the TIME BASE, PERIOD, and WIDTH controls to any convenient position.

(3) Using the oscilloscope, measure the trigger pulse amplitude and width. The trigger pulse amplitude should be about -1 volt, peak-to-peak; the pulse width should be about 10 nanoseconds.

SUBSECTION 4-4 PULSE WIDTH AND PERIOD TEST SETTINGS

TIME BASE (μs)	PULSE WIDTH (μs)*	PULSE RECORD (μs)
0.1	1	2 thru 9
0.1	1 thru 8	9
0.1	10	20,30,40,50, 60,70,80,90
0.1	10,20,30,40, 50,60,70,80	90
0.1	100	200,300,400, 500,600,700, 800,900
0.1	100,200,300, 400,500,600, 700,800	900
1.0	1	2 thru 9
1.0	1 thru 8	9
1.0	10	20,30,40,50, 60,70,80,90
1.0	10,20,30,40, 50,60,70,80	90
1.0	100	200,300,400, 500,600,700, 800,900
1.0	100,200,300, 400,500,600, 700,800	900
10	1	2 thru 9
10	1 thru 8	9
10	10	20,30,40,50, 60,70,80,90
10	10,20,30,40, 50,60,70,80	90
10	100	200,300,400, 500,600,700, 800,900
10	100,200,300, 400,500,600, 700,800	900
EXT.	As appropriate	As appropriate

*Pulse WIDTH control setting must be one digit (units, tens, or hundreds, as appropriate) less than the corresponding PERIOD control setting.

SECTION 5
PARTS LIST

5-1 ORDERING INFORMATION

Replacement parts may be ordered through your E-H Representative or from the factory. To be certain that you receive the proper replacement parts, always include the following information with your order:

a. Model number and serial number of the instrument on which the replacement parts will be installed.

b. Circuit or drawing reference for which each part is intended.

c. E-H Part Number.

For factory repair of this instrument, or warranty claim, contact E-H Research Laboratories, Inc., Customer Service Department, and provide:

(1) Instrument model number and serial number.
(2) Full details concerning the nature of the malfunction.

Individual components in this instrument that are identified by a 6-digit E-H part number may be replaced with parts of like

5-1 Continued

value and quality providing the replacement part is the same physical size and has the same value and tolerances specified in the parts list. Components identified with a 5-digit E-H part number, or marked with an asterisk (*), are factory selected or come in matched sets. Replacements for factory select parts should be ordered through your E-H Representative or from the factory.

The circuit or drawing reference numbers start with "1" on each etched circuit board. It is necessary to include the etched circuit board terminology in the circuit number to distinguish between the two.

Normally, individual wafers or contacts are not supplied for switch repair. If switch repair is necessary, it is more practical to replace the entire switch.

Etched circuit boards are available complete with mounted components. Refer to the following index for E-H part numbers. The individual components on each board are tabulated in the paragraph noted for that board.

INDEX

	E-H Part #s	Paragraph
CLOCK BOARD	D-11010	5-2
PRESET DECADE BOARD-01	D-11007	5-3
PRESET DECADE BOARD-02		5-4
GATE BOARD	D-11008	5-5
OUTPUT BOARD	D-11025	5-6
POWER SUPPLY BOARD	D-11009	5-7
MISCELLANEOUS		5-8

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-2	CLOCK BOARD	
C1	Cap.,.002uf,cer.	311-017
C2	Cap.,7-35pf, var.	333-004
C3	Cap.,.002uf,cer.	311-017
C4	Cap.,100pf,cer.	311-007
C5	Cap.,.002uf,cer.	311-017
C6	Cap.,.luf,50v,cer.	311-034
C7	Cap.,.luf,50v,cer.	311-034
C8	Cap.,7-35pf,var.	333-004
C9	Cap.,100pf,cer.	311-007
C10	Cap.,.02uf,cer.	311-039
C11	Cap.,luf,cer.	311-038
C12	Cap.,.luf,50v,cer.	311-034
C13	Cap.,7-35pf,var.	333-004
C14	Cap.,.luf,50v,cer.	311-034
C15	Cap.,.0luf,cer.	311-012
C16	Cap.,.00luf,cer.	311-010
C17	Cap.,50pf,cer.	311-006
C18	Cap.,.0luf,cer.	311-012
C19	Cap.,.00luf,cer.	311-010
C20	Cap.,100uf,25v,elect.	316-035
C21	Cap.,50pf,cer.	311-006
C22	Cap.,.00luf,cer.	311-010
C23	Cap.,.0luf,cer.	311-012
C24	Cap.,.0luf,cer.	311-012
C25	Cap.,.00luf,cer.	311-010
C26	Cap.,.luf,50v,cer.	311-034
C27	Cap.,20pf,cer.	311-002
C28	Cap.,20pf,cer.	311-002
C29	Cap.,.00luf,cer.	311-010
C30	Cap.,.00luf,cer.	311-010
C31	Cap.,.0luf,cer.	311-012
CR1	Diode, 1N2941	376-030
CR2	Diode, 1N2941	376-030
CR3	Diode, 1N270	376-031
CR4	Diode, 1N270	376-031
CR5	Diode, 1N270	376-031
CR6	Diode, 1N270	376-031
CR7	Diode, CGD1419	376-046
CR8	Diode, 1N751A	376-022
L1	Inductor,2.2uh	335-016
L2	Inductor,220uh	335-017
L3	Inductor,220uh	335-017
L4	Inductor	A11021-01
L5	Inductor,.68uh	335-013
Q1	Transistor, 2N706A	663-022
Q2	Transistor, 2N706A	663-022
Q3	Transistor, 2N706A	663-022
Q4	Transistor, 2N706A	663-022
Q5	Transistor, 2N706A	663-022
Q6	Transistor, 2N706A	663-022
Q7	Transistor, 2N706A	663-022
Q8	Transistor, 2N706A	663-022
Q9	Transistor, 2N966	663-032

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-2	Continued	
Q10	Transistor, 2N964	663-030
Q11	Transistor, 2N964	663-030
Q12	Transistor, 2N966	663-032
Q13	Transistor, 2N966	663-032
Q14	Transistor, 2N966	663-032
R1	Resistor,680,¼W,5%	595-681
R2	Resistor,68,¼W,5%	595-680
R3	Resistor,18K,¼W,5%	595-183
R4	Resistor,1.5K,¼W,5%	595-152
R5	Resistor,2.7K,¼W,5%	595-272
R6	Resistor,390,¼W,5%	595-391
R7	Resistor,2.7K,¼W,5%	595-272
R8	Resistor,240,¼W,5%	595-241
R9	Resistor,100,¼W,5%	595-101
R10	Resistor,1K,¼W,5%	595-102
R11	Resistor,10K,¼W,5%	595-103
R12	Resistor,10K,¼W,5%	595-103
R13	Resistor,6.2K,¼W,5%	595-622
R14	Resistor,510,¼W,5%	595-511
R15	Resistor,5.1K,¼W,5%	595-512
R16	Resistor,2.2K,¼W,5%	595-222
R17	Resistor,330,¼W,5%	595-331
R18	Resistor,1K.¼W,5%	595-102
R19	Resistor,100,¼w,5%	595-101
R20	Resistor,10K,¼W,5%	595-103
R21	Resistor,24K,¼W,5%	595-243
R22	Resistor,750,¼W,5%	595-751
R23	Resistor,3K,¼W,5%	595-302
R24	Resistor,680,¼W,5%	595-681
R25	Resistor,1.2K,¼W,5%	595-122
R26	Resistor,1K,¼W,5%	595-102
R27	Resistor,1.5K,¼W,5%	595-152
R28	Resistor,75,¼W,5%	595-750
R30	Resistor,1K,¼W,5%	595-102
R31	Resistor,270,¼W,5%	595-271
R32	Resistor,150,½W,5%	596-151
R33	Resistor,100,¼W,5%	595-101
R34	Resistor,330,½W,5%	596-331
R35	Resistor,470,¼W,5%	595-471
R36	Resistor,4.3K,¼W,5%	595-432
R37	Resistor,100,¼W,5%	595-101
R38	Resistor,1.5K,¼W,5%	595-152
R39	Resistor,1K,¼W,5%	595-102
R40	Resistor,270,¼W,5%	595-271
R41	Resistor,100,¼W,5%	595-101
R42	Resistor,150,½W,5%	596-151
R43	Resistor,330,½W,5%	596-331
R44	Resistor,910,¼W,5%	595-911
R45	Resistor,1.5K,¼W,5%	595-152
R46	Resistor,3.6K,¼W,5%	595-362
R47	Resistor,240,½W,5%	596-241
R48	Resistor,240,½W,5%	596-241

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-2	Continued	
R49	Resistor,1.5K,¼W,5%	595-152
R50	Resistor,1.1K,¼W,5%	595-112
R51	Resistor,1.5K,¼W,5%	595-152
R52	Resistor,3.6K,¼W,5%	595-362
R53	Resistor,910,¼W,5%	595-911
R54	Resistor,1.5K,¼W,5%	595-152
R55	Resistor,1.5K,¼W,5%	595-152
R56	Resistor,910,¼W,5%	595-911
R57	Resistor,3.6K,¼W,5%	595-362
R58	Resistor,10,¼W,5%	595-100
R59	Resistor,750,¼W,5%	595-751
R60	Resistor,51,1W,5%	597-510
R61	Resistor,120,1W,5%	597-121
R62	Resistor,1K,¼W,5%	595-102
R63	Resistor,1.5K,¼W,5%	595-152
5-3	PRESET DECADE-01	
C1	Cap.,25pf,cer.	311-003
C2	Cap.,500pf,cer.	311-009
C3	Cap.,75pf,cer.	311-025
C4	Cap.,75pf,cer.	311-025
C5	Cap.,75pf,cer.	311-025
C6	Cap.,75pf,cer.	311-025
C7	Cap.,500pf,cer.	311-009
C8	Cap.,25pf,cer.	311-003
C9	Cap.,500pf,cer.	311-009
C10	Cap.,75pf,cer.	311-025
C11	Cap.,75pf,cer.	311-025
C12	Cap.,75pf,cer.	311-025
C13	Cap.,75pf,cer.	311-025
C14	Cap.,500pf,cer.	311-009
C15	Cap.,25pf,cer.	311-003
C16	Cap.,500pf,cer.	311-009
C17	Cap.,75pf,cer.	311-025
C18	Cap.,75pf,cer.	311-025
C19	Cap.,75pf,cer.	311-025
C20	Cap.,75pf,cer.	311-025
C21	Cap.,500pf,cer.	311-009
C22	Cap.,25pf,cer.	311-003
C23	Cap.,500pf,cer.	311-009
C24	Cap.,15pf,cer.	311-035
C25	Cap.,75pf,cer.	311-025
C26	Cap.,75pf,cer.	311-025
C27	Cap.,75pf,cer.	311-025
C28	Cap.,100uf,25v,elect.	316-035
C29	Cap.,500pf,cer.	311-009
C30	Cap.,.001uf,cer.	311-010
CR1	Diode, CGD1419	376-046
CR2	Diode, CGD1419	376-046
CR3	Diode, CGD1419	376-046
CR4	Diode, CGD1419	376-046

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-3	Continued	
CR5	Diode, CGD1419	376-046
CR6	Diode, CGD1419	376-046
CR7	Diode, CGD1419	376-046
CR8	Diode, CGD1419	376-046
CR9	Diode, CGD1419	376-046
CR10	Diode, CGD1419	376-046
CR11	Diode, CGD1419	376-046
CR12	Diode, CGD1419	376-046
CR13	Diode, CGD1419	376-046
CR14	Diode, 1N270	376-031
CR15	Diode, 1N270	376-031
CR16	Diode, 1N270	376-031
CR17	Diode, 1N270	376-031
CR18	Diode, 1N270	376-031
CR19	Diode, 1N270	376-031
CR20	Diode, 1N270	376-031
CR21	Diode, 1N270	376-031
CR22	Diode, 1N270	376-031
CR23	Diode, 1N270	376-031
CR24	Diode, 1N270	376-031
CR25	Diode, 1N270	376-031
CR26	Diode, 1N270	376-031
CR27	Diode, 1N270	376-031
CR28	Diode, 1N270	376-031
CR29	Diode, 1N270	376-031
CR30	Diode, 1N270	376-031
CR31	Diode, 1N270	376-031
CR32	Diode, 1N270	376-031
CR33	Diode, 1N270	376-031
CR34	Diode, 1N270	376-031
CR35	Diode, 1N270	376-031
CR36	Diode, 1N270	376-031
CR37	Diode, 1N270	376-031
L1	Inductor,1.5uh	335-001
L2	Inductor	A11021-01
Q1	Transistor, 2N966	663-032
Q2	Transistor, 2N966	663-032
Q3	Transistor, 2N966	663-032
Q4	Transistor, 2N966	663-032
Q5	Transistor, 2N966	663-032
Q6	Transistor, 2N966	663-032
Q7	Transistor, 2N966	663-032
Q8	Transistor, 2N966	663-032
Q9	Transistor, 2N966	663-032
Q10	Transistor, 2N966	663-032
Q11	Transistor, 2N966	663-032
Q12	Transistor, 2N966	663-032
Q13	Transistor, 2N966	663-032
Q14	Transistor, 2N966	663-032
Q15	Transistor, 2N966	663-032
Q16	Transistor, 2N966	663-032

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-3 Continued		
Q17	Transistor, 2N966	663-032
Q18	Transistor, 2N834	663-028
Q19	Transistor, 2N834	663-028
R1	Resistor,6.8K,¼W,5%	595-682
R2	Resistor,6.8K,¼W,5%	595-682
R3	Resistor,1K,¼W,5%	595-102
R4	Resistor,1.8K,¼W,5%	595-182
R5	Resistor,2K.¼W,5%	595-202
R6	Resistor,200,½W,5%	596-201
R7	Resistor,200,½W,5%	596-201
R8	Resistor,130,¼W,5%	595-131
R9	Resistor,470,¼W,5%	595-471
R10	Resistor,100,¼W,5%	595-101
R11	Resistor,1.5K,¼W,5%	595-152
R12	Resistor,470,¼W,5%	595-471
R13	Resistor,1.5K,¼W,5%	595-152
R14	Resistor,470,¼W,5%	595-471
R15	Resistor,470,¼W,5%	595-471
R16	Resistor,100,¼W,5%	595-101
R17	Resistor,270,1W,5%	597-271
R18	Resistor,1.8K,¼W,5%	595-182
R19	Resistor,2K,¼W,5%	595-202
R20	Resistor,200,½W,5%	596-201
R21	Resistor,200,½W,5%	596-201
R22	Resistor,130,¼W,5%	595-131
R23	Resistor,470,¼W,5%	595-471
R24	Resistor,100,¼W,5%	595-101
R25	Resistor,1.5K,¼W,5%	595-152
R26	Resistor,470,¼W,5%	595-471
R27	Resistor,1.5K,¼W,5%	595-152
R28	Resistor,470,¼W,5%	595-471
R29	Resistor,470,¼W,5%	595-471
R30	Resistor,100,¼W,5%	595-101
R31	Resistor,270,1W,5%	597-271
R32	Resistor,1.8K,¼W,5%	595-182
R33	Resistor,2K,¼W,5%	595-202
R34	Resistor,200,½W,5%	596-201
R35	Resistor,200,½W,5%	596-201
R36	Resistor,130,¼W,5%	595-131
R37	Resistor,470,¼W,5%	595-471
R38	Resistor,100,¼W,5%	595-101
R39	Resistor,1.5K,¼W,5%	595-152
R40	Resistor,470,¼W,5%	595-471
R41	Resistor,1.5K,¼W,5%	595-152
R42	Resistor,470,¼W,5%	595-471
R43	Resistor,470,¼W,5%	595-471
R44	Resistor,100,¼W,5%	595-101
R45	Resistor,270,1W,5%	597-271
R46	Resistor,1.8K,¼W,5%	595-182
R47	Resistor,2K,¼W,5%	595-202
R48	Resistor,200,½W,5%	596-201
R49	Resistor,200,½W,5%	596-201
R50	Resistor,130,¼W,5%	595-131

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-3 Continued		
R51	Resistor,470,¼W,5%	595-471
R52	Resistor,100,¼W,5%	595-101
R53	Resistor,1.5K,¼W,5%	595-152
R54	Resistor,470,¼W,5%	595-471
R55	Resistor,1.5K,¼W,5%	595-152
R56	Resistor,470,¼W,5%	595-471
R57	Resistor,470,¼W,5%	595-471
R58	Resistor,100,¼W,5%	595-101
R59	Resistor,270,1W,5%	597-271
R60	Resistor,150,½W,5%	596-151
R61	Resistor,1K,¼W,5%	595-102
R62	Resistor,150,½W,5%	596-151
R63	Resistor,1K,¼W,5%	595-102
R64	Resistor,2.2K,¼W,5%	595-222
R65	Resistor,2.2K,¼W,5%	595-222
R66	Resistor,2.2K,¼W,5%	595-222
R67	Resistor,2.2K,¼W,5%	595-222
R68	Resistor,2.2K,¼W,5%	595-222
R69	Resistor,2.2K,¼W,5%	595-222
R70	Resistor,2.2K,¼W,5%	595-222
R71	Resistor,2.2K,¼W,5%	595-222
R72	Resistor,2.2K,¼W,5%	595-222
R73	Resistor,2.2K,¼W,5%	595-222
R74	Resistor,2.2K,¼W,5%	595-222
R75	Resistor,2.2K,¼W,5%	595-222
5-4 PRESET DECADE-02		
C1	Cap.,25pf,cer.	311-003
C2	Cap.,500pf,cer.	311-009
C3	Cap.,75pf,cer.	311-025
C4	Cap.,75pf,cer.	311-025
C5	Cap.,75pf,cer.	311-025
C6	Cap.,75pf,cer.	311-025
C7	Cap.,500pf,cer.	311-009
C8	Cap.,25pf,cer.	311-003
C9	Cap.,500pf,cer.	311-009
C10	Cap.,75pf,cer.	311-025
C11	Cap.,75pf,cer.	311-025
C12	Cap.,75pf,cer.	311-025
C13	Cap.,75pf,cer.	311-025
C14	Cap.,500pf,cer.	311-009
C15	Cap.,25pf,cer.	311-003
C16	Cap.,500pf,cer.	311-009
C17	Cap.,75pf,cer.	311-025
C18	Cap.,75pf,cer.	311-025
C19	Cap.,75pf,cer.	311-025
C20	Cap.,75pf,cer.	311-025
C21	Cap.,500pf,cer.	311-009
C22	Cap.,25pf,cer.	311-003
C23	Cap.,500pf,cer.	311-009
C24	Cap.,15pf,cer.	311-035
C25	Cap.,75pf,cer.	311-025

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-4 (Continued)		
C26	Cap.,75pf,cer.	311-025
C27	Cap.,75pf,cer.	311-025
C28	Cap.,100uf,25v,elect.	316-035
C29	Cap.,500pf,cer.	311-009
C30	Cap.,.001uf,cer.	311-010
CR1	Diode, CGD1419	376-046
CR2	Diode, CGD1419	376-046
CR3	Diode, CGD1419	376-046
CR4	Diode, CGD1419	376-046
CR5	Diode, CGD1419	376-046
CR6	Diode, CGD1419	376-046
CR7	Diode, CGD1419	376-046
CR8	Diode, CGD1419	376-046
CR9	Diode, CGD1419	376-046
CR10	Diode, CGD1419	376-046
CR11	Diode, CGD1419	376-046
CR12	Diode, CGD1419	376-046
CR13	Diode, CGD1419	376-046
CR14	Diode, 1N270	376-031
CR15	Diode, 1N270	376-031
CR16	Diode, 1N270	376-031
CR17	Diode, 1N270	376-031
CR18	Diode, 1N270	376-031
CR19	Diode, 1N270	376-031
CR20	Diode, 1N270	376-031
CR21	Diode, 1N270	376-031
CR22	Diode, 1N270	376-031
CR23	Diode, 1N270	376-031
CR24	Diode, 1N270	376-031
CR25	Diode, 1N270	376-031
CR26	Diode, 1N270	376-031
CR27	Diode, 1N270	376-031
CR28	Diode, 1N270	376-031
CR29	Diode, 1N270	376-031
CR30	Diode, 1N270	376-031
CR31	Diode, 1N270	376-031
CR32	Diode, 1N270	376-031
CR33	Diode, 1N270	376-031
CR34	Diode, 1N270	376-031
CR35	Diode, 1N270	376-031
CR36	Diode, 1N270	376-031
CR37	Diode, 1N270	376-031
L2	Inductor	A11021-01
Q1	Transistor, 2N966	663-032
Q2	Transistor, 2N966	663-032
Q3	Transistor, 2N966	663-032
Q4	Transistor, 2N966	663-032
Q5	Transistor, 2N966	663-032
Q6	Transistor, 2N966	663-032
Q7	Transistor, 2N966	663-032
Q8	Transistor, 2N966	663-032
Q9	Transistor, 2N966	663-032

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-4 (Continued)		
Q10	Transistor, 2N966	663-032
Q11	Transistor, 2N966	663-032
Q12	Transistor, 2N966	663-032
Q13	Transistor, 2N966	663-032
Q14	Transistor, 2N966	663-032
Q15	Transistor, 2N966	663-032
Q16	Transistor, 2N966	663-032
Q17	Transistor, 2N966	663-032
Q18	Transistor, 2N834	663-028
Q19	Transistor, 2N834	663-028
R1	Resistor,6.8K,⅛W,5%	595-682
R2	Resistor,6.8K,⅛W,5%	595-682
R3	Resistor,1K,⅛W,5%	595-102
R4	Resistor,1.8K,⅛W,5%	595-182
R5	Resistor,2K,⅛W,5%	595-202
R6	Resistor,200,½W,5%	596-201
R7	Resistor,200,½W,5%	596-201
R8	Resistor,130,⅛W,5%	595-131
R9	Resistor,470,⅛W,5%	595-471
R10	Resistor,100,⅛W,5%	595-101
R11	Resistor,1.5K,⅛W,5%	595-152
R12	Resistor,470,⅛W,5%	595-471
R13	Resistor,1.5K,⅛W,5%	595-152
R14	Resistor,470,⅛W,5%	595-471
R15	Resistor,470,⅛W,5%	595-471
R16	Resistor,100,⅛W,5%	595-101
R17	Resistor,270,1W,5%	597-271
R18	Resistor,1.8K,⅛W,5%	595-182
R19	Resistor,2K,⅛W,5%	595-202
R20	Resistor,200,½W,5%	596-201
R21	Resistor,200,½W,5%	596-201
R22	Resistor,130,⅛W,5%	595-131
R23	Resistor,470,⅛W,5%	595-471
R24	Resistor,100,⅛W,5%	595-101
R25	Resistor,1.5K,⅛W,5%	595-152
R26	Resistor,470,⅛W,5%	595-471
R27	Resistor,1.5K,⅛W,5%	595-152
R28	Resistor,470,⅛W,5%	595-471
R29	Resistor,470,⅛W,5%	595-471
R30	Resistor,100,⅛W,5%	595-101
R31	Resistor,270,1W,5%	597-271
R32	Resistor,1.8K,⅛W,5%	595-182
R33	Resistor,2K,⅛W,5%	595-202
R34	Resistor,200,½W,5%	596-201
R35	Resistor,200,½W,5%	596-201
R36	Resistor,130,⅛W,5%	595-131
R37	Resistor,470,⅛W,5%	595-471
R38	Resistor,100,⅛W,5%	595-101
R39	Resistor,1.5K,⅛W,5%	595-152
R40	Resistor,470,⅛W,5%	595-471
R41	Resistor,1.5K,⅛W,5%	595-152
R42	Resistor,470,⅛W,5%	595-471

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-4	(Continued)	
R43	Resistor,470,¼W,5%	595-471
R44	Resistor,100,¼W,5%	595-101
R45	Resistor,270,1W,5%	597-271
R46	Resistor,1.8K,¼W.5%	595-182
R47	Resistor,2K,¼W,5%	595-202
R48	Resistor,200,½W,5%	596-201
R49	Resistor,200,½W,5%	596-201
R50	Resistor,130,¼W,5%	595-131
R51	Resistor,470,¼W,5%	595-471
R52	Resistor,100,¼W,5%	595-101
R53	Resistor,1.5K,¼W,5%	595-152
R54	Resistor,470,¼W,5%	595-471
R55	Resistor,1.5K,¼W,5%	595-152
R56	Resistor,470,¼W,5%	595-471
R57	Resistor,470,¼W,5%	595-471
R58	Resistor,100,¼W,5%	595-101
R59	Resistor,270,1W,5%	597-271
R60	Resistor,150,½W,5%	596-151
R61	Resistor,1K,¼W,5%	595-102
R62	Resistor,150,½W,5%	596-151
R63	Resistor,1K,¼W,5%	595-102
R64	Resistor,2.2K,¼W,5%	595-222
R65	Resistor,2.2K,¼W,55	595-222
R66	Resistor,2.2K,¼W,5%	595-222
R67	Resistor,2.2K,¼W,5%	595-222
R68	Resistor,2.2K,¼W,5%	595-222
R69	Resistor,2.2K,¼W,5%	595-222
R70	Resistor,2.2K,¼W,5%	595-222
R71	Resistor,2.2K,¼W,5%	595-222
R72	Resistor,2.2K,¼W,5%	595-222
R73	Resistor,2.2K,¼W,5%	595-222
R74	Resistor,2.2K,¼W,5%	595-222
R75	Resistor,2.2K,¼W,5%	595-222
5-5	GATE BOARD	
C1	Cap.,50pf,cer.	311-006
C2	Cap.,100pf,cer.	311-007
C3	Cap.,100pf,cer.	311-007
C4	Cap.,50pf,cer.	311-006
C5	Cap.,.01uf,cer.	311-012
C6	Cap.,100uf,25v,elect.	316-035
C7	Cap.,50pf,cer.	311-006
C8	Cap.,.001uf,cer.	311-010
C9	Cap.,500pf,cer.	311-009
C10	Cap.,50pf,cer.	311-006
C11	Cap.,75pf,cer.	311-025
C12	Cap.,100pf,cer.	311-007
CR1	Diode, 1N751A,zener	374-022
CR2	Diode, 1N270	376-031
CR3	Diode, CGD1419	376-046
CR4	Diode, CGD1419	376-046
CR5	Diode, 1N749,zener	374-044

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-5	(Continued	
CR6	Diode, CGD1419	376-046
CR7	Diode, CGD1419	376-046
CR8	Diode, 1N749,zener	374-044
CR9	Diode, CGD1419	376-046
CR10	Diode, CGD1419	376-046
CR11	Diode, CGD1419	376-046
CR12	Diode, 1N751A,zener	374-022
CR13	Diode, CGD1419	376-046
CR14	Diode, CGD1419	376-046
L1	Inductor	A11021-01
Q1	Transistor, 2N966	663-032
Q2	Transistor, 2N966	663-032
Q3	Transistor, 2N966	663-032
Q4	Transistor, 2N966	663-032
Q5	Transistor, 2N706A	663-022
Q6	Transistor, 2N966	663-032
Q7	Transistor, 2N966	663-032
Q8	Transistor, 2N966	663-032
Q9	Transistor, 2N966	663-032
Q10	Transistor, 2N966	663-032
Q11	Transistor, 2N966	663-032
Q12	Transistor, 2N706A	663-022
Q13	Transistor, 2N966	663-032
Q14	Transistor, 2N966	663-032
Q15	Transistor, 2N966	663-032
Q16	Transistor, 2N966	663-032
Q17	Transistor, 2N966	663-032
Q18	Transistor, 2N966	663-032
Q19	Transistor, 2N966	663-032
Q20	Transistor, 2N966	663-032
Q21	Transistor, 2N966	663-032
R1	Resistor,150,½W,5%	596-151
R2	Resistor,200,¼W,5%	595-201
R3	Resistor,1K,¼W,5%	595-102
R4	Resistor,150,½W,5%	596-151
R5	Resistor,270,1W,5%	597-271
R6	Resistor,499,½W,1%,MF	618-001
R7	Resistor,523,½W,1%,MF	618-019
R8	Resistor,1K,¼W,5%	595-102
R9	Resistor,1K,¼W,5%	595-102
R10	Resistor,1K,½W,5%	596-102
R11	Resistor,150,¼W,5%	595-151
R12	Resistor,150,¼W,5%	595-151
R13	Resistor,1.5K,½W,1%,MF	618-014
R14	Resistor,1K,½W,1%,MF	618-007
R15	Resistor,750,½W,5%	596-751
R16	Resistor,160,1W,5%	597-161
R17	Resistor,1.5K,¼W,5%	595-152
R18	Resistor,1.5K,¼W,5%	595-152
R19	Resistor,750,½W,5%	596-751
R20	Resistor,1K,½W,1%,MF	618-007
R21	Resistor,1.5K,½W,1%,MF	618-014

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-5 (Continued)		
R22	Resistor,150,¼W,5%	595-151
R23	Resistor,150,¼W,5%	595-151
R24	Resistor,1K,¼W,5%	596-102
R25	Resistor,1K,¼W,5%	595-102
R26	Resistor,499,½W,1%,MF	618-001
R27	Resistor,523,½W,1%,MF	618-019
R28	Resistor,150,½W,5%	596-151
R29	Resistor,270,1W,5%	597-271
R30	Resistor,200,¼W,5%	595-201
R31	Resistor,1K,¼W,5%	595-102
R32	Resistor,150,½W,5%	596-151
R33	Resistor,1K,¼W,5%	595-102
R34	Resistor,270,¼W,5%	595-271
R35	Resistor,1.5K,¼W,5%	595-152
R36	Resistor,330,½W,5%	596-331
R37	Resistor,180,½W,5%	596-181
R38	Resistor,100,¼W,5%	595-101
R39	Resistor,750,½W,5%	596-751
R40	Resistor,1K,½W,5%	596-102
R41	Resistor,1K,¼W,5%	595-102
R42	Resistor,1K,¼W,5%	595-102
R43	Resistor,316,½W,1%,MF	618-008
R44	Resistor,909,½W,1%	601-011
R45	Resistor,1.24K,½W,1%,MF	618-003
R46	Resistor,316,½W,1%,MF	618-008
R47	Resistor,750,¼W,5%	595-751
R48	Resistor,51,¼W,5%	595-510
R49	Resistor,1K,¼W,5%	595-102
5-6 OUTPUT BOARD		
C1	Cap.,.00luf,cer.	311-010
C2	Cap.,.00luf,cer.	311-010
C3	Cap.,.05uf,cer.	311-021
C4	Cap.,2.2uf,25v,cer.	311-019
C5	Cap.,.0luf,cer.	311-012
C6	Cap.,.00luf,cer.	311-010
C7	Cap.,.0luf,cer.	311-012
C8	Cap.,.0luf,cer.	311-012
C9	Cap.,.luf,cer.	311-014
C10	Cap.,.00luf,cer.	311-010
C11	Cap.,.luf,cer.	311-014
C12	Cap.,.luf,cer.	311-014
C13	Cap.,.luf,cer.	311-014
C14	Cap.,20pf	10954
C15	Cap.,.0luf,cer.	311-012
C16	Cap.,2.2uf,25v,cer.	311-019
C17	Cap.,.00luf,cer.	312-001
C18	Cap.,.0luf,cer.	312-003
C19	Cap.,300pf	10952
C20	Cap.,.00luf,cer.	311-010
C21	Cap.,25uf,25v,elect.	316-028

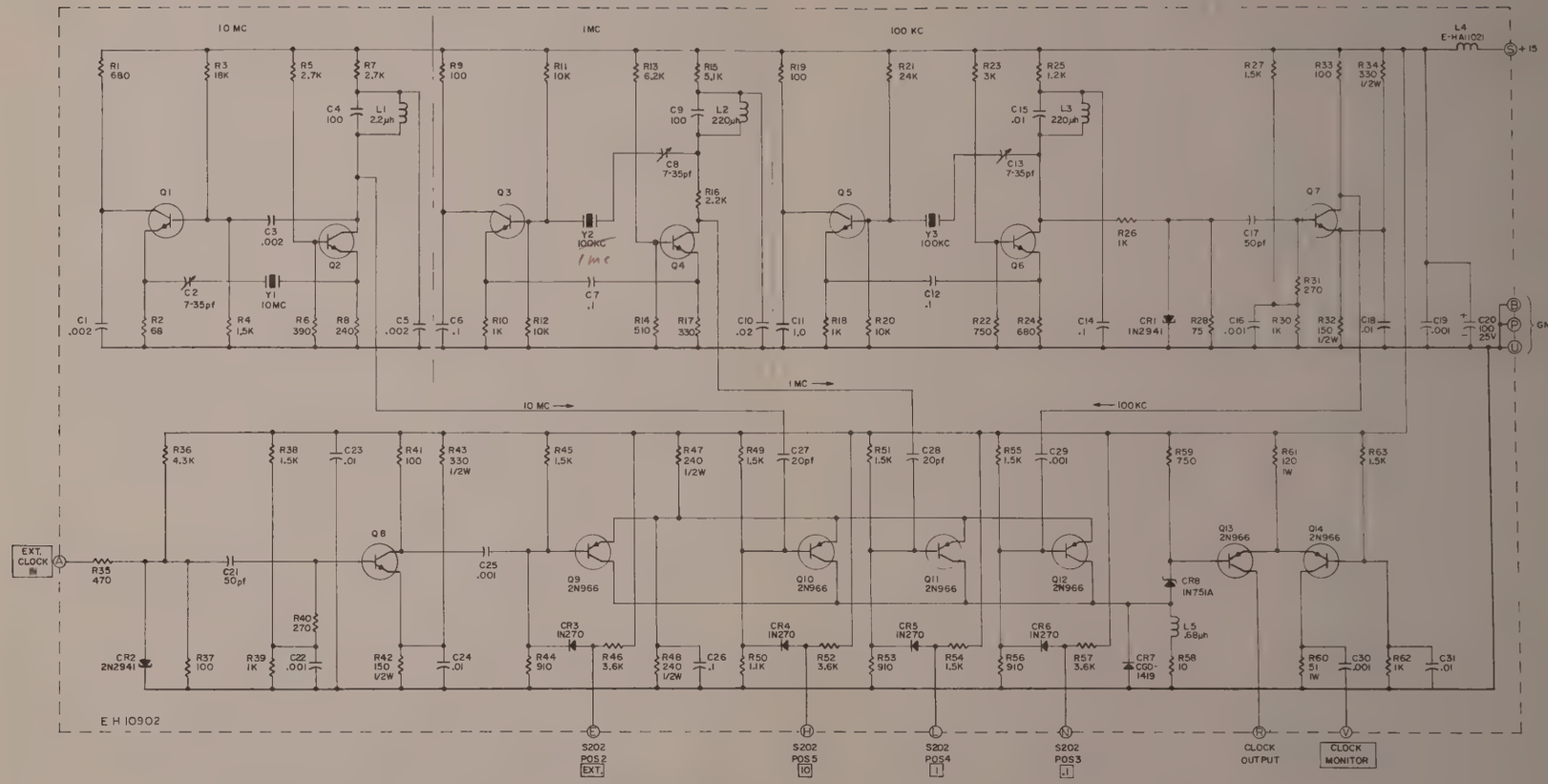
CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-6 (Continued)		
C22	Cap.,.luf,cer.	311-014
C23	Cap.,2.2uf,25v,cer.	311-019
C24	Cap.,100uf,25v,elect	316-035
C25	Cap.,100uf,25v,elect.	316-035
C26	Cap.,.luf,50v,cer.	311-034
CR1	Diode, 1N270	376-031
CR2	Diode, 1N270	376-031
CR3	Diode, 1N270	376-031
CR4	Diode, 1N270	376-031
CR5	Diode, 1N270	376-031
CR6	Diode, 1N270	376-031
CR7	Diode, 1N270	376-031
CR8	Diode, 1N270	376-031
CR9 & CR10	Diode, 1N759A, matched pair zener	11733
CR10	See CR9	
CR11	Diode, 1N749A, zener	374-044
CR12	Diode, 1N3686A, zener	374-041
CR13	Diode	11764
CR14	Diode	11764
CR15	Diode	11764
CR16	Diode	11764
CR17	Diode	11742
CR18	Diode	11764
CR19	Diode	11764
CR21	Diode, 1N3789A	374-027
CR22	Diode, 1N914B	376-022
L1	Inductor,2.2uh	335-016
L2	Inductor	10995
L3	Inductor	10956
L4	Inductor	10956
L5	Inductor	12121
L6	Inductor	10996
L7	Inductor,2.2uh	335-016
L8	Inductor,.33uh	335-010
Q1	Transistor, 2N966	663-032
Q2	Transistor, 2N966	663-032
Q3	Transistor, 2N834	663-028
Q4	Transistor, 2N966	663-032
Q5	Transistor, 2N1132	663-024
Q6	Transistor	11701
Q7	Transistor, 2N1132	663-024
Q8	Transistor, 2N834	663-028
Q9	Transistor, 2N2369A	663-089
Q10	Transistor, 2N2950	663-039
Q11	Transistor	11711
Q12	Transistor	11725
Q13	Transistor	11701
Q14	Transistor	11701
Q15	Transistor	11705
Q16	Transistor	11701
R1	Resistor,300,¼W,5%	595-301
R2	Resistor,300,¼W,5%	595-301

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-6 (Continued)		
R3	Resistor,300,⅛W,5%	595-301
R4	Resistor,300,⅛W,5%	595-301
R5	Resistor,51,½W,5%	596-510
R6	Resistor,51,½W,5%	596-510
R7	Resistor,240,1W,5%	597-241
R8	Resistor,2.2K,½W,5%	596-222
R9	Resistor,160,½W,5%	596-161
R10	Resistor,180,½W,5%	596-181
R11	Resistor,2.2K,½W,5%	596-222
R12	Resistor,51,½W,5%	596-510
R13	Resistor,270,½W,5%	596-271
R14	Resistor,2.7K,½W,5%	596-272
R15	Resistor,1K,½W,5%	596-102
R16	Resistor,470,½W,5%	596-471
R17	Resistor,430,½W,5%	596-431
R18	Resistor,1K,½W,5%	596-102
R19	Resistor,2K,½W,5%	596-202
R20	Resistor,2K,½W,5%	596-202
R21	Resistor,360,1W,5%	597-361
R22	Resistor,1K,½W,5%	596-102
R23	Resistor,2.4K,½W,5%	596-242
R24	Resistor,300,½W,5%	596-301
R25	Resistor,15K,½W,5%	596-153
R26	Resistor,240,½W,5%	596-241
R27	Resistor,180,½W,5%	596-181
R28	Resistor,510,½W,5%	596-511
R29	Resistor,240,½W,5%	596-241
R30	Resistor,33,¼W,5%	595-330
R31	Resistor,100,¼W,5%	595-101
R32	Resistor,2.7,½W,5%	596-027
R33	Resistor,1K,½W,5%	596-102
R34	Potentiometer,1K	550-031
R35	Resistor,3.3K,½W,5%	596-332
R36	Resistor,2K,½W,5%	596-202
R37	Resistor,4.3K,½W,5%	596-432
R38	Resistor,4.3K,½W,5%	596-432
R39	Resistor,6.2K,½W,5%	596-622
R40	Resistor,2K,½W,5%	596-202
R41	Resistor,430,1W,5%	597-431
R42	Resistor,180,1W,5%	597-181
R43	Resistor,91,½W,5%	596-910
R44	Resistor,3K,½W,5%	596-302
R45	Resistor,3.6K,½W,5%	596-362
R46	Resistor,1.8K,½W,5%	596-182
R47	Resistor,10,1W,5%	597-100
R48	Resistor,180,1W,5%	597-181
R49	Resistor,10,1W,5%	597-100
R50	Resistor,200,¼W,5%	595-201
R51	Resistor,200,¼W,5%	595-201
R52	Resistor,200,¼W,5%	595-201
R53	Resistor,10,¼W,5%	595-100
R54	Resistor,30,½W,5%	596-300
R55	Resistor,10,¼W,5%	595-100

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-7 POWER SUPPLY BOARD		
C1	Cap.,100uf,25v,elect.	316-035
C2	Cap.,100uf,25v,elect.	316-035
C3	Cap.,10uf,25v,elect.	316-044
C4	Cap.,25uf,25v,elect.	316-028
C5	Cap.,50uf,75v,elect.	316-050
C6	Cap.,100uf,25v,elect.	316-035
C7	Cap.,25uf,25v,elect.	316-028
C8	Cap.,100uf,25v,elect.	316-035
C9	Cap.,25uf,25v,elect.	316-028
Q1	Transistor, 2N1303	663-011
Q2	Transistor, 2N250	663-026
Q3	Transistor, 2N1303	663-011
Q4	Transistor, 2N250	663-026
Q5	Transistor, 2N1303	663-011
R1	Resistor,1.2K,½W,5%	596-122
R2	Resistor,1K,½W,5%	596-102
R3	Resistor,100,½W,5%	596-101
R4	Resistor,2K,½W,5%	596-202
R5	Resistor,220,2W,5%	598-221
R6	Resistor,1.24K,⅛W,1%	618-003
R7	Resistor,1.21K,½W,1%	601-081
R8	Resistor,1.5K,½W,5%	596-152
R9	Resistor,1K,½W,5%	596-102
R10	Resistor,2K,½W,5%	596-202
R11	Resistor,100,½W,5%	596-101
R12	Resistor,5.11K,½W,1%,MF	618-020
R13	Resistor,100K,½w,5%	596-104
R14	Resistor,3.01K,½W,1%,MF	618-018
R15	Resistor,1.24K,½W,1%	618-003
R16	Resistor,1.21K,½W,1%	601-081
R17	Resistor,100,½W,5%	596-101
R18	Resistor,1K,½W,5%	596-102
R19	Resistor,1K,½W,5%	596-102
5-8 MISCELLANEOUS		
C101	Cap.,1500uf,75v,elect.	316-049
C102	Cap.,250uf,12v,elect.	316-031
C103	Cap.,100uf,25v,elect.	316-035
C104	Cap.,1500uf,75v,elect.	316-049
C105	Cap.,1500uf,75v,elect.	316-049
C201	Cap.,.25uf,mylar	320-021
C202	Cap.,.07uf,mylar	320-020
C203	Cap.,.025uf,mylar	320-017
C204	Cap.,.007uf,poly.	326-008
C205	Cap.,.0025uf,poly.	326-011
C206	Cap.,820pf,cer.	311-027
C207	Cap.,250pf,cer.	311-004
C208	Cap.,50pf,cer.	311-006
CR101	Diode, 1N253	376-041
CR102	Diode, 1N253	376-041

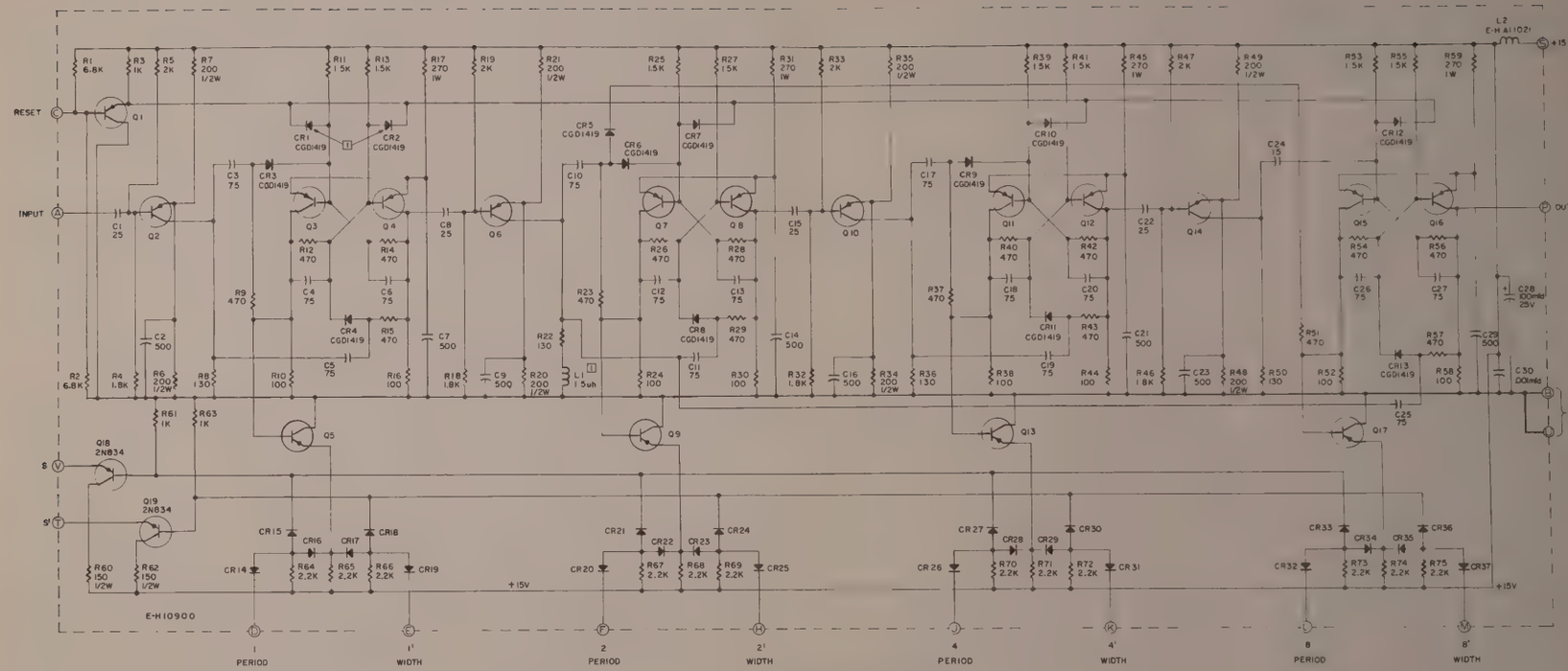
CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-8 (Continued)		
CR103	Diode, 1N253	376-041
CR104	Diode, 1N253	376-041
CR105	Diode, 1N2071	376-034
CR106	Diode, 1N2071	376-034
CR107	Diode, 1N2071	376-034
CR108	Diode, 1N2071	376-034
CR109	Diode, 1N3024	374-055
CR110	Diode, 1N3016	374-042
CR201	Diode, 1N270	376-031
CR202	Diode, 1N270	376-031
CR203	Diode, 1N270	376-031
CR204	Diode, 1N270	376-031
CR205	Diode, 1N270	376-031
CR206	Diode, 1N270	376-031
CR207	Diode, 1N270	376-031
CR208	Diode, 1N270	376-031
CR209	Diode, 1N270	376-031
CR210	Diode, 1N270	376-031
CR211	Diode, 1N270	376-031
CR212	Diode, 1N270	376-031
CR213	Diode, 1N270	376-031
CR214	Diode, 1N270	376-031
CR215	Diode, 1N270	376-031
CR216	Diode, 1N270	376-031
CR217	Diode, 1N270	376-031
CR218	Diode, 1N270	376-031
CR219	Diode, 1N270	376-031
CR220	Diode, 1N270	376-031
CR221	Diode, 1N270	376-031
CR222	Diode, 1N270	376-031
CR223	Diode, 1N270	376-031
CR224	Diode, 1N270	376-031
CR225	Diode, 1N270	376-031
CR226	Diode, 1N270	376-031
CR227	Diode, 1N270	376-031
CR228	Diode, 1N270	376-031
DL1	Delay Line,10ns	11023
L101	Inductor	10564
L102	Inductor	10563
Q101	Transistor, 2N250	663-026
Q102	Transistor, 2N250	663-026
Q103	Transistor, 2N250	663-026
Q104	Transistor, 2N250	663-026
Q105	Transistor, 2N250	663-026
Q106	Transistor, 2N250	663-026
Q107	Transistor, 2N250	663-026
Q108	Transistor, 2N250	663-026
R101	Resistor,.5,10W,WW	610-034
R102	Resistor,1K,½W,5%	596-102
R103	Resistor,240,½W,5%	596-241
R104	Resistor,300,1W,5%	597-301

CIRCUIT REFERENCE	DESCRIPTION	E-H PART NO.
5-8 (Continued)		
R105	Resistor,300,½W,5%	596-301
R106	Potentiometer,500,2W	545-034
R107	Resistor,75,½W,5%	596-750
R108	Resistor,240,½W,5%	596-241
R109	Potentiometer,500,2W	545-034
R110	Potentiometer,25K	545-007
R111	Potentiometer,25K	545-007
R113	Resistor,51,1W,5%	597-510
R201	Resistor,100K,½W,5%	596-104
R202	Potentiometer,2.5K	550-009
R203	Potentiometer, 2.5K	550-009
R204	Resistor,680,½W,5%	596-681
R205	Resistor,680,½W,5%	596-681
R206	Potentiometer,2.5K	550-009
R207	Potentiometer,5K	550-003
S201	Switch, POWER	630-006
S202	Switch, TIME BASE	624-043
S203	Switch, PERIOD	639-004
S204	Switch, WIDTH	639-004
S205	Switch, RAMP TIME/10v	624-020
S206	Switch, POLARITY	624-044
S207	Switch, ATTENUATOR	639-003
T101	Transformer	10562



NOTES: UNLESS NOTED
1. ALL RESISTORS 1/4W, 5%
2. ALL CAPACITORS IN MFD.
3. ALL TRANSISTORS 2N706A

CLOCK BOARD
(A1)
17:

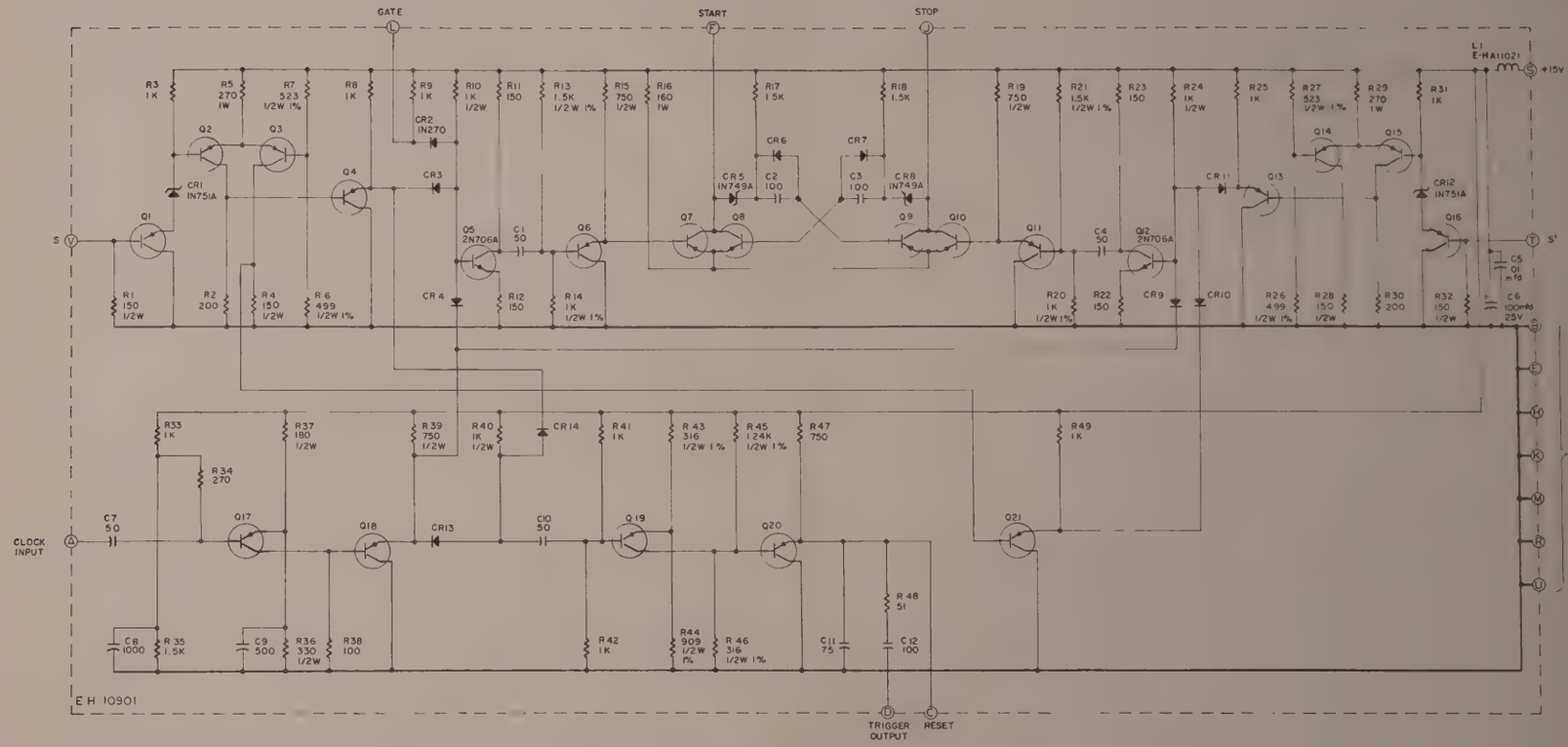


NOTES: UNLESS OTHERWISE SPECIFIED

[1] VARIATIONS:
D-11002-01 DIODE CR2 USED, CR1 REMOVED.
D-11002-02 " CR1 " CR2 "
D-11002-01 CHOKE L1 USED.
D-11002-02 " " DELETED & SHORT USED.

2. ALL TRANSISTORS 2N966
3. ALL DIODES IN270.
4. ALL RESISTORS 1/4W, 5%
ALL CAPACITORS IN mmfd

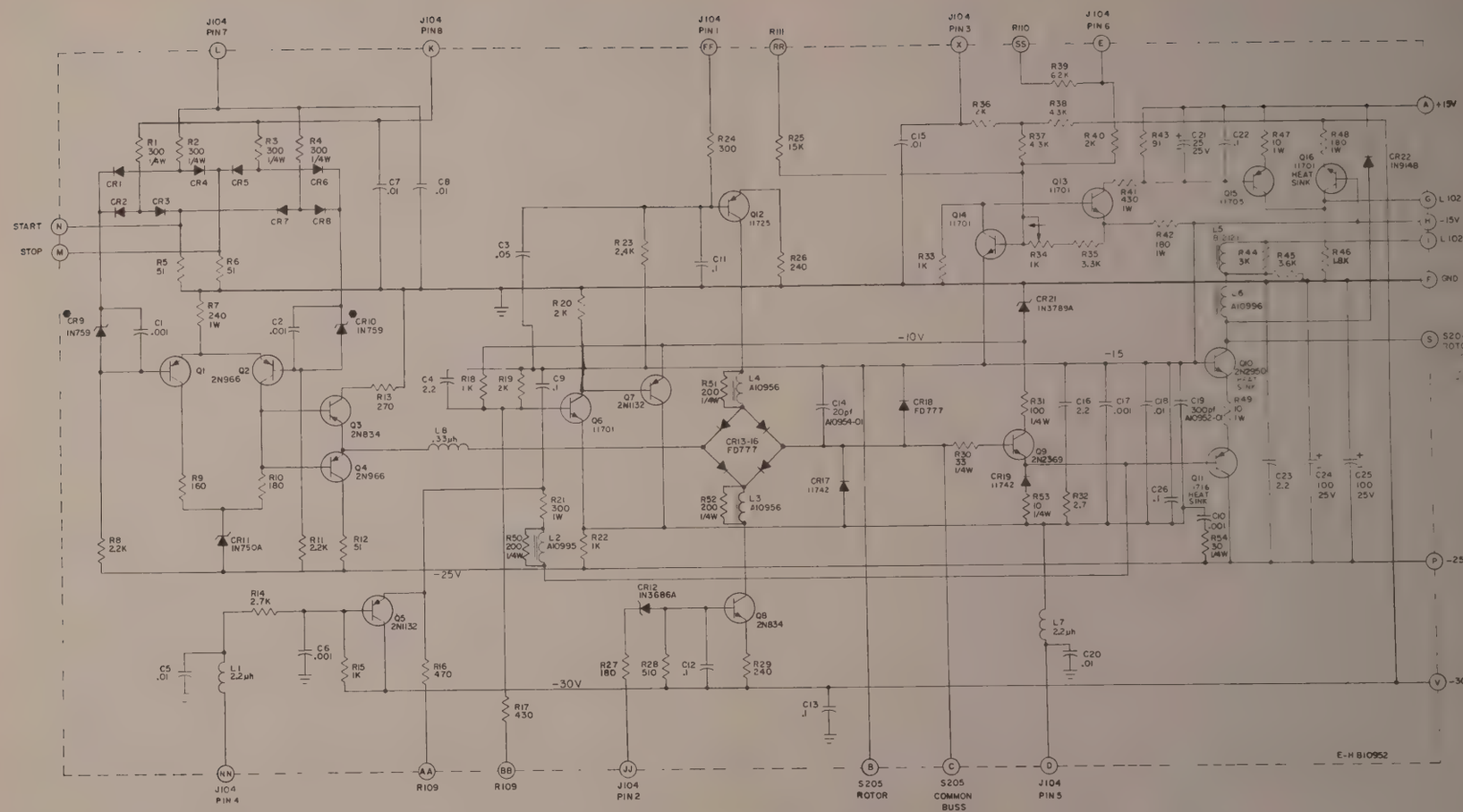
PRESET DECADE (A) 171 2



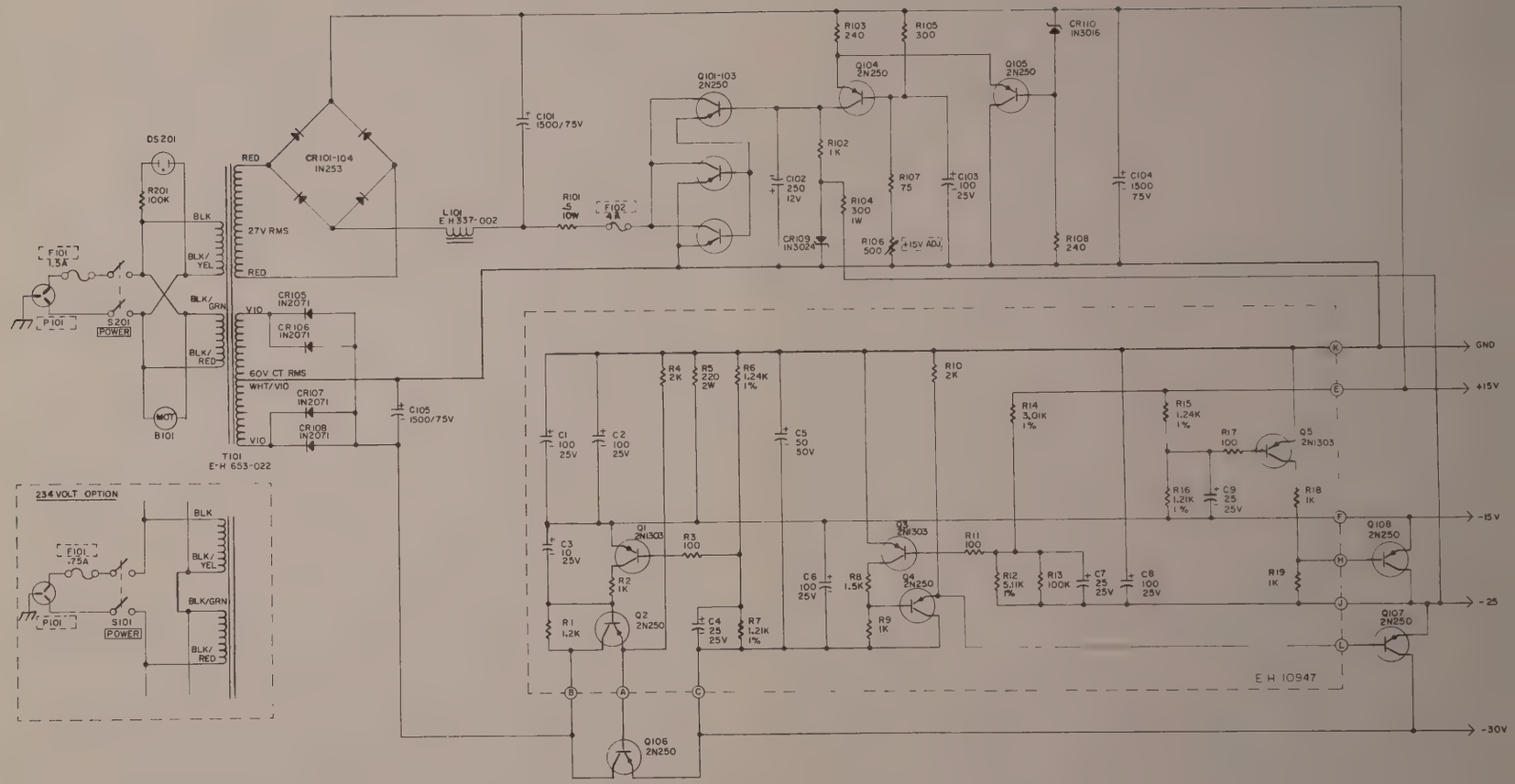
NOTES: UNLESS NOTED
1. ALL TRANSISTORS ARE 2N966
2. ALL RESISTORS ARE 1/4W, 5%
3. ALL CAPACITORS ARE IN MMFD.
4. ALL DIODES CGD 1419

GATE BOARD (A) 171

3



OUTPUT BOARD (A) 171 4

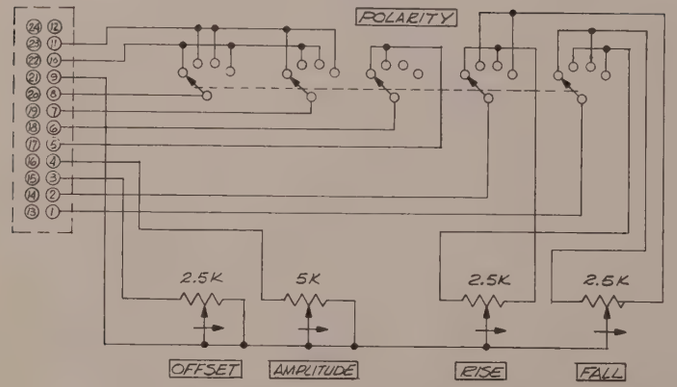


NOTES: UNLESS NOTED
1. ALL RESISTORS 1/2W, 5%
2. ALL CAPACITORS ARE IN MFD.

POWER SUPPLY 5
(A) (7)

External Output Control

"EXT. OUT CONTROL J104" MATING PLUG
AMPHENOL BLUE RIBBON 57-30240



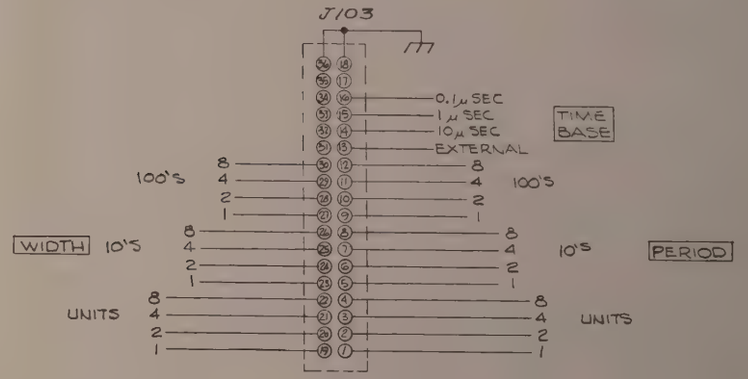
TO RESTORE INTERNAL CONTROLS WITHOUT REPLACING P.C. BOARD JUMPERS, INSERT DUMMY EXTERNAL PLUG AS FOLLOWS

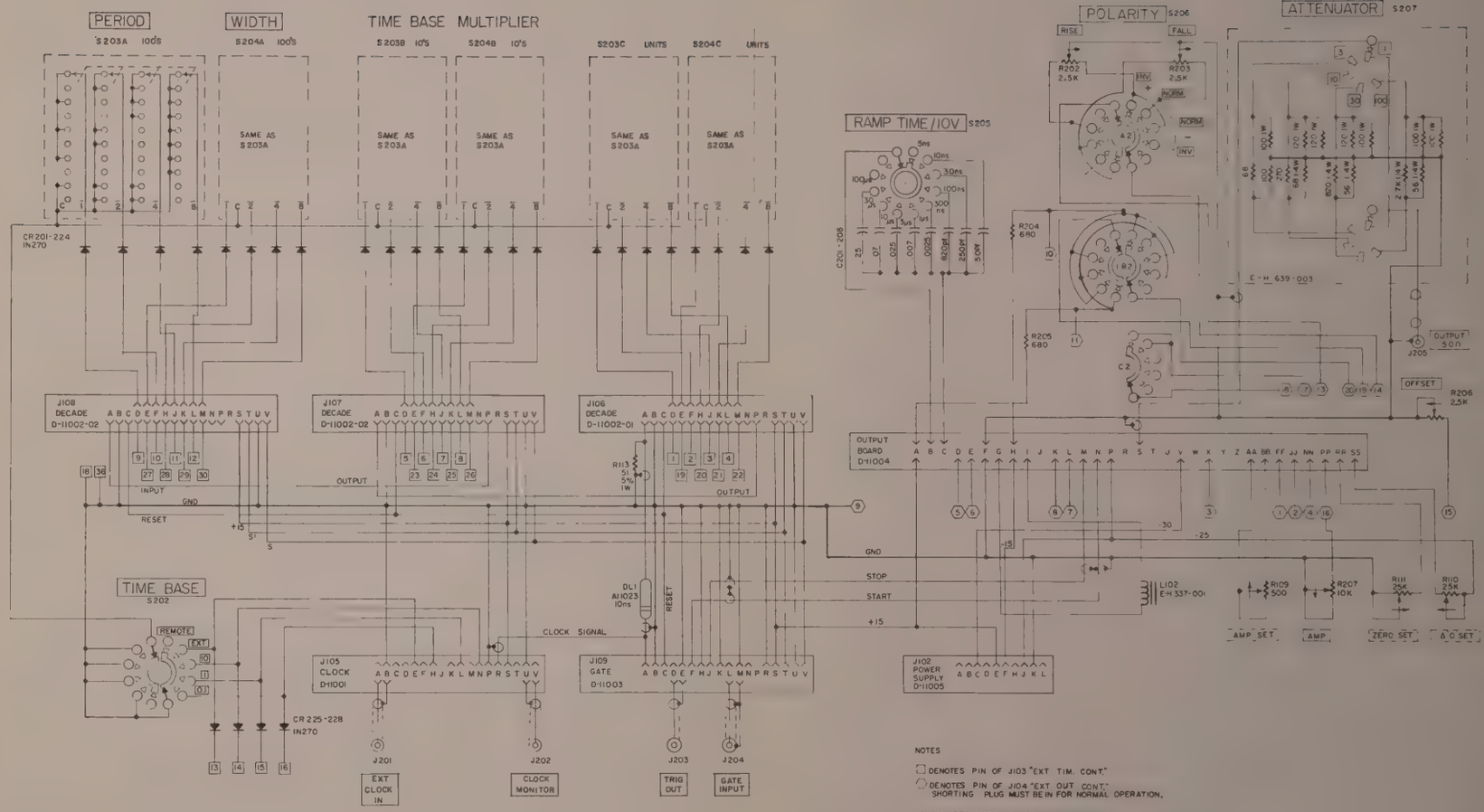
External Timing Control

TO OPPERATE EXTERNALLY

STEP I
SWITCH "TIME BASE" FRONT PANEL CONTROL TO "REMOTE."

STEP II
SHORT APPROPRIATE REMOTE PLUG (AMPHENOL BLUE RIBBON 57-30360) PINS TO GROUND PINS 18 & 36 AS FOLLOWS;
(a) SELECT TIME BASE BY GROUNDING ONE OF PINS 13-16.
(b) SELECT PERIOD AND WIDTH MULTIPLIER BY GROUNDING THE BINARY CODED DECIMAL (BCD) COMPLEMENT OF THE NUMBER DESIRED.
e.g. TO SELECT PERIOD MULTIPLIER 543
543 = 100 + 400
+40
+2+1
} GROUND PINS 12, 10, 8, 6, 5, 4 & 3





NOTES

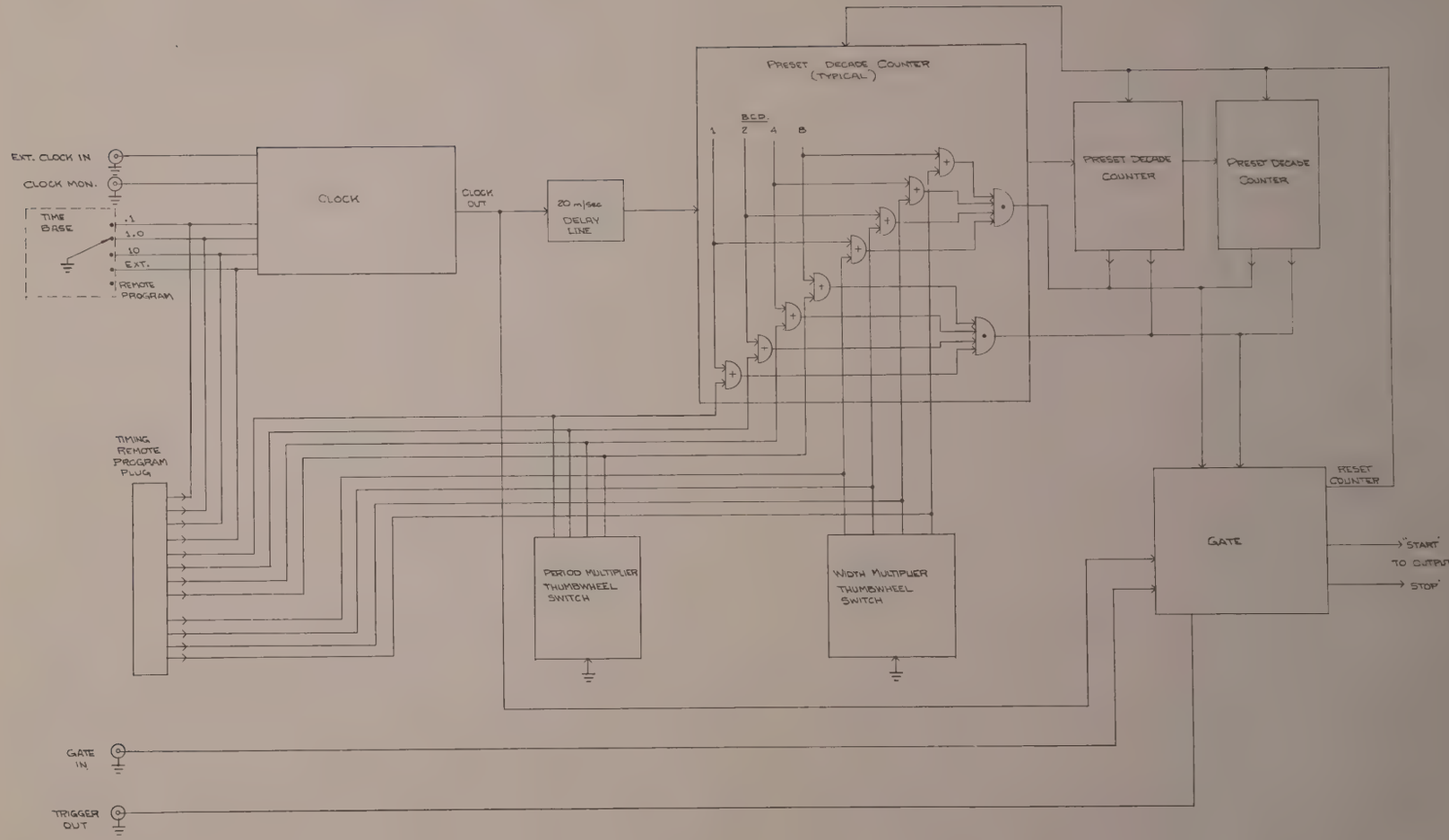
□ DENOTES PIN OF J103 "EXT TIM. CONT."

○ DENOTES PIN OF J104 "EXT OUT CONT." SHORTING PLUG MUST BE IN FOR NORMAL OPERATION.

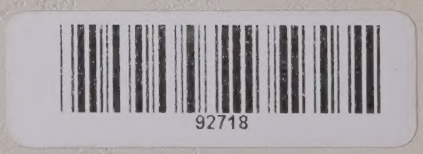
1. ALL RESISTORS 1/2W 5% UNLESS NOTED
2. ALL CAPACITORS IN MFD. UNLESS NOTED
3. SWITCHES VIEWED FROM SHAFT END & ARE IN FULL C.C.W. POSITION.

MASTER SCHEMATIC (A) 171

7



BLOCK DIAGRAM (A) .71 8


92718